THE REPUBLIC OF AZERBAIJAN

On the rights of manuscript

ABSTRACT

of the dissertation for the degree of Doctor of Science

ECOLOGICAL ASSESSMENT AND ENDEMISM OF PLANTS IN FOREST AND HIGH-MOUNTAIN LANDSCAPES OF THE GREATER CAUCASUS (WITHIN AZERBAIJAN)

Specialty:	2426.01 - Ecology
Field of science:	Biology
Applicant:	**Elman Farhad Yusifov**

BAKU – 2025

The dissertation work has been carried out in the Institute of Botany of Ministry of Science and Education of the Republic of Azerbaijan and in the Institute of Soil Science and Agrochemistry of the Republic of Azerbaijan.

Scientific supervisors:

Full member of ANAS
Garib Shamil Mammadov

Doctor of biological sciences, professor
Sayyara Jamshid İbadullayeva

Official opponents:

Corresponding member of ANAS
Ilham Eyub Shahmuradov

Doctor of biological sciences, professor
Elman Osman Isgender

Doctor of biological sciences, associate professor **Sevil Akif Mammadli**

Doctor of biological sciences
Vafa Khalil Gasimova

One-time Dissertation Council BED 1.07/1 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Institute of Microbiology of the Ministry of Science and Education of the Republic of Azerbaijan.

Chairman of Dissertation council:

Corresponding member of ANAS
Panah Zulfikar Muradov

Scientific secretary of Dissertation council:

Doctor of Philosophy in biology, associate professor
Gunel Ali Gasimova

Chairman of the scientific seminar:

Doctor of biological sciences, associate professor
Samira Imamyar Nadjafova

INTRODUCTION

Relevance and degree development of the topic. Since Biological Diversity is a unique form of manifestation of living nature, the concept of biodiversity occupies a significant place in the field of modern biological sciences and environmental policy. It is thanks to him that the structural-functional organization of ecosystems is formed, the stability and sustainability of ecosystems during changes in the environment caused by natural and anthropogenic influences is ensured. According to the provisions of the convention on Biological Diversity, Biological Diversity cannot be protected if the habitats of plants and animals – natural territorial complexes (landscapes) - are not protected. The Council of Europe notes in the "Pan-European strategy for the protection of Biological Diversity and landscape diversity" that the problem of landscape diversity and Biological Diversity is one of the actual directions of modern fundamental and applied research[1,2]. The soil cover of the area is one of the main components of the landscape. The UN Convention on the Fight against Desertification specifically states that soil degradation and desertification problems are the main risks to biodiversity. On the other hand, the physicochemical properties of the soil are among the most fundamental factors that determine the vital forms of biodiversity that develop on it.

In the National Report on Biological Diversity of the Republic of Azerbaijan, "excessive use of biodiversity" is also mentioned among the reasons that directly affect the loss of biodiversity in country studies. Forest and high-mountainous landscapes of the Greater Caucasus are under extreme pressure in this regard.

The vegetation of these landscapes is used as a source of resources, pastures and hayfields. The influence of unregulated

[1] Pan-European Biological and Landscape Diversity Strategy Implementation: Set the Basis for National Ecological Network of Ukraine. – Kyiv : National Ecological Centre of Ukraine, – 2003. – 80 p.

[2] Azərbaycan Respublikasının Bioloji Müxtəliflik üzrə Ölkə Tədqiqatları. Bioloji Müxtəliflik üzrə Birinci Milli Məruzə. // – Bakı: Əlfərül, – 2004, – s.109.

grazing, domestic animals and introduced invasive species directly affects the biological diversity of the territory, landscapes with biota of these species, and indirectly negatively affects the change of landscapes. The flora diversity of the mentioned areas, especially the flora of the Alpine-subalpine and subnival landscapes, has been studied very weakly, sporadically. The relatively low anthropogenic impact of high-mountainous landscapes makes it possible to investigate the patterns of relations between plant associations common here. These plants, which have a short growing period and adapted to cold environments, are very sensitive to climate changes.

The drift of habitats under conditions of global climate change increases the importance of these studies. On the other hand, the studies conducted so far have been belt-based and ecosystem-based. The main work in belt-type studies is carried out against the background of hypsometric parameters. At this time, the accuracy of the obtained studies is not high because the slopes and exposures are ignored. Because the climatic conditions (solar radiation, temperature regime, wind speed, soil moisture) of the northern slope and the southern slope at the same height are not the same. As a result, the difference in habitats, vegetation period leads to the formation of different plant formations in these areas.

In the ecosystem approach, only a specific ecosystem is examined. However, at this time, the ecotones where the two ecosystems intersect are left out of consideration. For example, many plants are found in clearings on the edges of forested areas and are closely related to the forest. On the other hand, the ecosystem approach focuses on living organisms. In the landscape approach, all factors have equal rights. Such an approach allows to study the regularities of the florogenesis of species and the relationships between them.

There is a special interest in the biological diversity of high mountain landscapes from a biological, ecological and physiological point of view. Because these organisms live in a relatively harsh climatic conditions, and their areal are relatively small, changes in climatic factors are reflected in the size of the population of these creatures. As a result, it is relatively easy to investigate the patterns

of the impact of climate changes on living populations. The main difference of the research work from previous works is that the main focus here is on hypsometric biogeography and dreyfi of Biological Diversity, endemism and the causes that generate it are investigated in the context of climate changes, and a more accurate classification of endemism is given.

Object and subject of research. The object of study is the flora of forest, subalpine-alpine and subnival landscapes of the Greater Caucasus in the borders of Azerbaijan. The subject of the study is the study of the biogeographic dependence and genesis of the endemism and ecological assessment of the diversity of flora of the mentioned area, the study of the impact of global climate changes on the flora and phytocenosis structure of the area.

Purpose and objectives of the research. The main goal is to study the biogeography of the flora of the territories of the Greater Caucasus in the borders of Azerbaijan, the drift of species, the distribution of categories and status across landscapes, ecological assessment, the investigation of the mechanism of florogenesis and endemism, providing extrapolations in the context of climate changes and developing mitigating measures. For this, the following tasks are planned:

- analysis and ecological assessment of taxonomic structure of flora diversity in forest and highland landscapes;
- analysis of dependence of flora diversity on soil factor, endemism, factors affecting endemism and florogenesis processes, relationships between these factors in Forest and high-altitude landscapes of research areas;
- analysis of flora diversity of forest and high-altitude landscapes of research areas in the context of climate change;
- development of the basic principles of sustainable development of the flora diversity of the territory.

Research methods. The materials were collected during the expeditionary research for 2013-2022, and samples stored in the scientific literature and herbarium fund were analyzed. During the assessment of the biological diversity of the mentioned landscapes, the results of environmental monitoring studies, statistical data,

Country studies and national reports on biodiversity of the Republic of Azerbaijan, national reports on Biological Diversity, climate change, national reports on the protection and sustainable use of Biological Diversity, National Action programs on Environmental Protection, scientific articles and monographs were also used.

The main provisions of the defense.

- The species represented in the forest and highland flora spread in the Azerbaijan borders of the Greater Caucasus are divided into 3 groups according to their richness and areal dynamics - developing, stable and sensitive species;
- Species move to higher elevations due to climate change. As a result of this drift, while the areas of some species (xerophytes and thermophytes) are expanding, the areas of others (cryophytes) are shrinking, the structure of the phytocenosis is changing;
- Against the background of climate changes, the morphological structure of plants and ecological life forms have a significant impact on the areal dynamics of species;
- The areas of endemic species of the area are spread within the boundaries of the Caucasian ecoregion;
- There is a directly proportional relationship between endemism and altitude. Thus, as the altitude increases, the number and percentage of endemic species increases;
- Relief, lithology, geological structure, microclimate, ground and surface water, soil, flora and fauna are the main factors affecting endemism;
- The surrounding areas of Bazarduzü peak are one of the breeding centers of the Greater Caucasus.

Scientific novelty of the research. The landscape analysis and taxonomic analysis of the flora of the Greater Caucasus in the forest, alpine-subalpine and subnival landscapes of the plants distributed in the borders of Azerbaijan was carried out, where a total of 1466 higher plant species were identified. Of them, 885 species are widespread, and 581 species are endemic species of various colors. Endemic species, in turn, are classified into 6 categories, 6 of which are endemic to Azerbaijan;

For the first time, 672 species belonging to 87 families and 315 genera were identified in the forest landscapes of Azerbaijan. Among them, 156 species are endemic species of different categories and make up 23% of landscape flora. 663 species belonging to 66 families and 321 genera were identified in the subalpine-alpine landscapes of Azerbaijan. Among them, 342 species are endemic species of different categories and make up 52% of landscape flora. In the subnival landscapes of Azerbaijan, 131 species belonging to 28 families and 83 genera have been determined. Among them, 83 species are endemic species of different categories and make up 63% of landscape flora.

The soil cover spread in each landscape and its characteristic indicators, taxonomic analysis of leading and sensitive species growing on these soils, morphological structure and life forms of pioneer plants are given.

The endemism of landscapes, the hypsometric dependence of endemism was studied and its classification was given in different categories, a total of 581 endemic species were identified.

The impact of climate changes on the flora diversity of forest and highland landscapes has been investigated and predictions have been made. In the last 100 years, the average annual temperature in the territory of Azerbaijan has increased by 0.3-0.8 °C, depending on the regions, the average annual precipitation in the republic has decreased by 23%, excluding some regions[3, 4]. This has led to the melting of glaciers in the territory of the country and a sharp decrease in the level of high mountain lakes. As a result of the melting of glaciers, the average annual temperature of the air in alpine-subalpine landscapes has increased, and the level of groundwater has decreased. Bu hal ərazidə yayılmış rütubətsevən və su bitkilərinə *(Potamogeton* L., *Mentha* L., *Carex* L., *Hordeum* L.,

[3] Сафаров, С. Г. Изменение температурного режима на территории Азербайджана // – Баку: Гидрометеорол и экол., – 2007. № 4, – с. 37–46.

[4] Мамедов, Р. М., Сафаров, С. Г., Сафаров, Э. С. Современные изменения режима атмосферных осадков на территории Азербайджана // Новосибирск: – География и природные ресурсы., – 2009. – № 4, – с. 56-62.

Juncus L., *Epilobium* L. və s.*)* mənfi təsir etməkdədir. Yağıntıların azalması, qışda qar örtüyünün azalmasına, qışın sərt vaxtlarında alp-subalp bitkilərinin kök sisteminin şaxtadan məhv olma risklərini artmasına səbəb olur. Səthi kök sisteminə malik bitkilər daha böyük risk altında olur. Artıq iqlimin qlobal istiləşməsi nəticəsində *Juncus effusus* L., *J.bufonius* L., *Cardamine uliginosa* M.Bieb., *Ephedra procera* C.A.Mey., *Alopecurus arundinaceus* Poir., *Carex diandra* Roth., *C.heleonastes subsp. heleonates (C.leporina* Schkuhr ex Trevir*), Epipactis palustris* (L.) Crantz, *E.microphylla* (Ehrh) Sw, *Ranunculus arachnoideus* C.A.Mey., *Pulsatilla violacea* Rupr. və s. növlər yüksəkliyə doğru 100-300 m dreyf etmişlər. Nəticədə bəzi növlərin arealları getdikcə azalmış, yüksəkliklərdəki fitosenozların tərkibi dəyişmişdir.

This situation has a negative effect on the moisture-loving and aquatic plants (*Potamogeton* L., *Mentha* L., *Carex* L., *Hordeum* L., *Juncus* L., *Epilobium* L., etc.) common in the area. A decrease in precipitation leads to a decrease in snow cover in winter, and an increase in the risk of destruction of the root system of alpine-subalpine plants due to frost in harsh winters. Plants with shallow root systems are at greater risk. *Juncus effusus* L., *J.bufonius* L., *Cardamine uliginosa* M.Bieb., *Ephedra procera* C.A.Mey., *Alopecurus arundinaceus* Poir., *Carex diandra* Roth., *C.heleonastes* subsp. *heleonates* (*C.leporina* Schkuhr ex Trevir), *Epipactis palustris* (L.) Crantz, *E.microphylla* (Ehrh) Sw, *Ranunculus arachnoideus* C.A.Mey., *Pulsatilla violacea* Rupr. etc. species drifted 100-300 m towards the height. As a result, the areas of some species have gradually decreased, and the composition of phytocenoses at altitudes has changed.

Theoretical and practical sifnificanse of the research. The obtained results show that accurate inventory of local flora is important in terms of sustainability and accurate assessment of areas of plant populations and plant resources. The results of the conducted researches are an important database for the more accurate determination of the areas, category and status, endemism of the plants belonging to the flora of Azerbaijan, and for the compilation of the next editions of "Flora of Azerbaijan", "Red Book of

Azerbaijan". The review of the endemism of the area, the factors determining the endemism, the structural analysis of florogenesis, the results obtained on the proposed new classification system are important scientific fundamental information on florogenesis and theoretical botanical research. The application of these data to other landscapes (semi-desert, meadow, steppe), plant communities, as well as faunal studies is of great scientific importance. The compiled list of sub-regional red lists of flora diversity of the area and old trees will have an important impact on the sustainable development of biological diversity.

Publication, dissertation approval and application. 19 scientific works (14 articles, 5 theses) related to the dissertation were published. 12 of them were published in journals indexed and summarized in international databases (Web of Science, Scopus, Agris, РИНЦ). Materials of the dissertation were presented at the International Symposium on “Проблемы ихтиологии и гидробиологии в странах Центральной Азии” (Bishkek, 2017), at the VIII International Symposium on "Steppes of Northern Eurasia" (Orenburg, 2018), “Экосистемные услуги и менеджмент природных ресурсов” (Tyumen, 2019), at the international scientific-practical conference on “Экология и эволюция: новые горизонты” (Yekaterinburg, 2019), at the IX International Symposium on "Steppes of Northern Eurasia" (Orenburg, 2021), “Актуальные проблемы экологиии природопользования“ at the XXIII international scientific-practical conference (Moscow, 2022), at the International Conference on “Biodiversity, land and water resources of Shusha and surrounding areas: vision for the future” (Baku, 2022), “Second Internatioal Bilateral Workshop on Science between Dokuz Eylul University and Azerbaijan National international scientific seminar on Academy of Sciences" (Baku-Izmir, 2022), International online scientific seminar on ”Актуальные вопросы изучения арктических и субарктических экосистем в условиях глобальных изменений природной среды и климата“ (Salexard, 2022), the international forum on ”Ecology and sustainable development of the environment along the Silk Road

economy“ (Urumqi, 2023), the X International Symposium on ”The steppes of Northern Eurasia" (Orenburg, 2024).

Names of the organizations where the dissertation work is carried out. Dissertation work was carried out in the Institute of Soil Science and Agrochemistry and in the Institute of Botany of the Ministry of Science and Education of the Republik of Azerbaijan .

The total volume and structure of the dissertation. Dissertation consists of introduction and 8 chapters, conclusions and recommendations, 340 names of used literature list. 200 of the literature used in the dissertation are works published in the last 10 years. The dissertation consist of 433 364 characters.

.

MAIN CONTENT OF WORK

CHAPTER I

HISTORY OF TERRITORY STUDY AND LITERATURE REVIEW

1.1. Conducted research on forest and high-mountainous landscapes of the planet.

Flora diversity of the forest and highland landscapes of the planet and neighboring areas, various effects of climate changes on species, transformation processes and the structure of biocenoses, endemism of highland landscapes, the nature and characteristics of the pressures on it have been studied in sufficient detail.

1.2. Studies on forest and high mountain landscapes of the Greater Caucasus.

The flora of the northern slopes of the Greater Caucasus has been sufficiently studied. Detailed information on 4,579 plant species belonging to 6 departments, 11 classes, 106 orders, 184 families,

1075 genera, including 1300 Caucasian endemics is given here [5,6]. Extensive studies have been conducted on the flora and endemism of the highlands of the southern slopes of the western part of the Greater Caucasus [7].

1.3. Researches on flora of forest and high-mountain landscapes of the Greater Caucasus in the borders of Azerbaijan.

In recent times, a number of fundamental studies have been conducted on the comprehensive study and ecological evaluation of the flora of the Greater Caucasus, which is spread within the borders of Azerbaijan, and the biotic and abiotic factors affecting it. The land cover of the area is one of the main factors that shape its flora. The main soils distributed in Azerbaijan, including the Greater Caucasus, were studied on the basis of modern scientific approaches and technologies [8,9]. GIS maps of land cover were compiled. In the studies dedicated to the flora of Azerbaijan, the species composition, category and status of the higher plants of our national flora, and the characteristics of plant associations were investigated[10,11]. Həmçinin,

---

[5] Иванов, А.Л. Конспект флоры Российского Кавказа (сосудистые растения) /А.Л.Иванов. – Ставрополь: Изд-во СКФУ, – 2019. – 341 с.

[6] Муртазалиев, Р.А. Анализ эндемиков флоры Восточного Кавказа и особенности их распространения // Вестник Дагестанского научного центра, – 2012. № 47, – с. 81–85.

[7] Shetekauri, Sh., Gagnidze, R. Diversity of high-mountain endemic flora of the Greater Caucasus Biological and landscape diversity of Georgia (Proceeding of the First National Conference) – Tbilisi: – 1999. – p. 151-158.

[8] Məmmədov, Q.Ş. Azərbaycanın torpaq ehtiyatlarından səmərəli istifadənin sosial-iqtisadi və ekoloji əsasları / Q.Ş. Məmmədov. – Bakı: Elm, – 2007. – 856 s.

[9] Babayev, M.R. Böyük Qafqazın müasir torpaq örtüyü / M.R. Babayev, Ə.M. Cəfərov, Ç.M. Cəfərova [və s.]. – Bakı: Elm, – 2017. –344 s.

[10] Ibadullayeva, S.C., An overview of the plant diversity of Azerbaijan. Biodiversity, Conservation and Sustainability in Asia. Prospects and Challenges in West Asia and Caucasus / S.C. Ibadullayeva, I.M. Huseynova // Springer, 1: – 2021, – p. 431-499.

[11] Qurbanov, E.M. Azərbaycanın bitki örtüyü / E.M. Qurbanov. – Bakı: Elm, – 2024. – 536 s.

Böyük Qafqaz meşələrinin aid olduğu meşə tipləri, dendroflorası üzrə tədqiqatlar aparılıb, yüksək dağlıq ekosistemlərinə dair kompleks məlumatlar verilir [12] , [13] . Azərbaycan florasının endemizminə dair klassik tədqiqatlar Qrossheym tərəfindən aparılmışdır və florada 240 endemik növün olduğu qeyd edilib. Sonrakı dövrlərdə bu məlumatlar müxtəlif alimlər tərəfindən daha da dəqiqləşdirilib. Mənbələrdə endemik növlərin sayı müxtəlif dövrlərdə müxtəlif rəqəmlərlə qiymətləndirilib[14,15].

CHAPTER II
MATERIALS AND RESEARCH METHODS

The main materials and data on the work were collected by the author on the basis of the expedition research and scientific literature materials in the years 2013-2020 based on the route method in forested and mountainous areas.

During the ecological evaluation of the biological diversity of the forest and highland landscapes, the results of environmental monitoring studies by many scientists, cartographic maps and samples stored in the herbarium fund of the Botanical Institute of ARETN were used. Comparative, historical and statistical analyzes were used during the processing of the obtained data, floristic and geobotanical data of the reviewed areas were collected, and phenological and ecological observations were recorded. Repeated expeditions were made to many areas in different seasons.

Review of the systematics and endemism of the species composition of the territories "Определитель растений Кавказа", "Plantation of Azerbaijan", "Сонспект флоры Российского

[12] Hacıyev, V.C. Azərbaycanın yüksək dağlıq bitkiliyinin ekosistemi / V.C. Hacıyev. – Bakı: Elm, – 2004. – 130 s.
[13] Məmmədov Q., Xəlilov M. Azərbaycanın meşələri / Q. Məmmədov, M. Xəlilov. – Bakı: Region Press, – 2022. – 624 s.
[14] Ахундов, Ф.Г. Эндемы флоры Азербайджана: / автореф. дис. докт.биол.наук. / Баку, 1973. – 44 с.
[15] Əsgərov, A.M. Azərbaycan florasının endemizminn analizi // Azərbaycan Milli Elmlər Akademiyasinin Məruzələri, Botanika. – 2014, c. LXX, №1. – s. 1-6.

Кавказа" [5], “Расстения Российского Западного Кавказа”[16] based on the sources. Classification of coastal and aquatic vegetation, their role in cleaning water bodies, indicator evaluations against pollution, indicator value of the main hydrophytes distributed in the area Sadchikov A.P., Kudryashov M.A. made on the basis of evaluations[17]. Geobotanical, ecological and biogeographic studies, systematics of plant communities, ecological assessment, ecological scales were carried out on the basis of appropriate methodologies [18, 19, 20, 21, 22]. Torpaqlar və torpaqların ekoloji qiymətləndirilməsi “Coğrafi informasiya sistemləri əsasında interaktiv elektron torpaq və torpaqların ekoloji qiymət xəritələrinin tərtibinə dair metodik göstəriş” əsasında həyata keçirilib. Növlərin təyinatı “Флора Азербайджана”, “Флора Кавказа”, “Основы биоморфологии семенных растений” əsərlərində qeyd edilmiş morfoloji təyinat və əlamətlərlə yoxlanılmışdır.

Latin names, systematics, endemism of plants plantarium.ru (Растения и лишайники России и сопредельных стран: отновый онлайн atlas и передитель растений), powo.science.kew.org (Plants of the World Online), worldfloraonline.org (The World Flora Online), gbif.org (Global Biodiversity Information Facility)

---

[16] Зернов, А.С. Растения Российского Западного Кавказа. [Полевой атлас] / А.С. Зернов. – М.: Т-во научных изданий КМК, – 2022. – 449 с.

[17] Садчиков, А.П. Экология прибрежно-водной растительности / А.П. Садчиков, М.А. Кудряшов. – М.: Изд-во НИА-Природа: РЭФИА, – 2004. – 220 с.

[18] Басов, В.М. Практикум по анатомии, морфологии и систематике растений. В.М. Басов, Т.В. Ефремова. – Москва: ЛЕНАНД, –2022. – 238 с.

[19] Терехина, Н.В. Полевая учебная практика по биогеографии: учебго-методическое пособие / Н.В. Терехина. – СПб.: Изд-во С.Петерб. ун-та, – 2022. –106 с.

[20] Ростоскуев, В.В. Моседирование экологических систем / В.В. Ростоскуев. – СПб: Изд-во СПбГУ, – 2012. – 80 с.

[21] Жукова, Л.А. Экологические шкалы и методы анализа экологического разнообразия растений / Л.А. Жукова, Ю.А. Дорогова, Н.В. Турмухаметова, [и др.]. Йошкар-Ола: – 2010. – 368 с.

[22] Məmmədov, Q.Ş., Coğrafi informasiya sistemləri əsasında interaktiv elektron torpaq və torpaqların ekoloji qiymət xəritələrinin tərtibinə dair metodik göstəriş / Q.Ş. Məmmədov, A.T. Alıyev, L.C. Qasımov [və b.]. – Bakı; Elm, – 2018. – 80 s.

platforms, according to international botanical nomenclatur[23]. The analysis of recent literature data shows that the areas of the vast majority of endemic species of forest and highland flora within the boundaries of the research areas have changed significantly. The limit area of the biogeography of these species coincides with the boundaries of the Caucasus ecoregion. The Caucasian ecoregion covers the territories of 6 neighboring states (Figure 1).

Figure 1. Map of the Caucasus Ecoregion (580 000 km^2)

It includes the Greater Caucasus, Lesser Caucasus, Talysh, Colchis (RF, Azerbaijan, Georgia, Armenia), adjacent mountainous areas of Turkey and Iran. It includes macroendemics within the Caucasus ecoregion, subendemic species found on both sides of the

[23] Нухимовский, Е.Л. Основы биоморфологии семенных растений: [В 3-х томах] / Е.Л. Нухимовский. – М: Недра, – т.1. – 1997.– 629 с.

Greater and Lesser Caucasus, and only South Caucasus endemics, Caucasus and Pontus endemics, and finally Caucasus and Elbrus endemics[24]. Biogeographic analysis of flora diversity in the research work was carried out on this ecoregion.

Floristic analysis of Tugay forests was studied in the areas of Kurgiraghi Garayazi, Alazan-Ayrichay, Gozluchay, Velvale-Jimichay, Akhsuchay, Girdimanchay.

Studies on lowland forests were conducted in the areas of Samur-Yalama. Studies on medium-mountainous forests were conducted in the areas of Zagatala, Guba, Ismayilli, Agdash, Khizi and Altyaghaj. Mountainous forests were studied in the areas of Zagatala State Nature Reserve, Altyaghaj National Park, Shahdag National Park, Balakan, Sheki and Gakh. Arid forests were studied in the areas of Varafta range, Budugh-Ruk pass, Turyanchay State Nature Reserve, Axar-Bahar, etc. High mountain landscapes were studied in Ismayilli, Gusar, Guba, Gabala, Zagatala (around Mount Gubek), Gakh (around Mount Akhvay), etc. areas, in the surrounding areas of Shahdag (Shah Yaylag), Tufandag, Bazaryurd, Bazarduzu mountain systems, Khanyaylaq (Sheki), Arakchin Plateau, Mikhtoken Range (Shamakhi), etc. Herbaria collected during the expeditions were transferred to the herbarium fund of the Institute of Botany.

CHAPTER III
THE MAIN FACTORS FORMING THE DIVERSITY OF FLORA OF THE FOREST, ALPINE, SUBALPINE AND SUBNIVAL BELTS OF THE GREATER CAUCASUS

3.1. Geological structure and relief of the territory.

The relief, geological development, and tectonic structure of the territory were formed on the basis of various exogenous relief-

[24] Zazanashvili, N. The Boundaries and Biophysical Features of the Caucasus Ecoregion. / N. Zazanashvili, K. Manvelyan, E. Askerov [et al.] // Ecoregional Conservation Plan for the Caucasus 2020. Edition Supplementary Reports, – Tbilisi: – 2020. – p. 6-20.

forming processes. The main orographic elements encountered here are related to the tectonic structure of the plates, sediments on them, and erosion of various origins. From a geological point of view, Azerbaijan is considered one of the complex and unique regions of the Alpine fold zone. It was formed in the zone where the Eurasian and African-Arabian lithospheric plates collide and is referred to the Alpine fold belt. The relief diversity of the territory is very complex and rich. Here, there are mainly 7 relief types (high, intensively dissected wrinkled-slippery nival-glacial mountains; high and medium-intensively dissected wrinkled-slippery mountains; low, partially intensively dissected wrinkled mountains; intensively dissected wrinkled erosional mountains; water-glacial plains; alluvial-proluvial, inclined, weakly dissected plains; accumulative, alluvial-proluvial dissected plains). The orographic structure of the area is formed by more than 40 ridges. The height of the main part of these ridges varies in the range of 3000–4000 m. The type of high and intensively dissected wrinkled-slippery nival-glacial mountains is widespread at altitudes of 3000–4466 m in the area. The area is rich in terms of igneous rocks and embodies the periods from the Mesozoic to the Cenozoic. The Mesozoic and Cenozoic sediments are better developed in the area[25,26]. Mesozoic magmatism in the Greater Caucasus dates back to the Jurassic and Cretaceous periods (170-145 million years ago). The relief diversity of the area is very complex and rich. There are mainly 7 relief types here. At altitudes of 3000-4466 m in the area, the high and intensively dissected wrinkled-crested nival glacial mountains type is widespread.

3.2. The climate of the region.

One of the most important abiotic factors affecting biological diversity is the climate factor. The unique geographical location of

[25] Azərbaycan Respublikasının Coğrafiyası / Baş redaktor: R. M. Məmmədov. – Bakı: Elm, – c. III– 2015. – s. 45-56.
[26] Azərbaycan Respublikası Milli Atlas. Bakı Kartoqrafiya fabriki, Bakı, 2014. – s. 84.

the territory, its complex relief, the Caspian Sea, intense solar radiation, and its location at the intersection of air masses of different origins are the main factors determining its climate. The unique ratio of climate-forming factors such as surface structure, solar radiation, atmospheric circulation, as well as air temperature, precipitation, humidity, evaporation, cloudiness, and wind regime, has led to the emergence of a rich variety of climate types in the territory.

In the studied area of the Greater Caucasus, 5 out of 11 climate types (temperate-warm climate with dry winters; cold climate with dry winters; temperate warm climate with approximately equal distribution of precipitation; cold climate with humid winters; mountain tundra climate) are observed.

3.3. Internal waters and water basins of the territory.

The river system of the area is made up of 17 rivers. Their length is 50-416 km, and the height of their sources is in the range of 1500-3800 m. The largest rivers are the Ganikh or Alazan (416 km), Gabyrri (389 km), Samur (216 km), Pirsaat (202 km) and Turyanchay (170 km) rivers. The number of main lakes in the area is 10. The area of the lakes is 0.01-0.03 km2, and the volume is in the range of 0.03-0.15 mln. m3. The largest lakes are Ajinohur, Ziyilnohur, Turfangol.

3.4. Soil cover of the territory.

The soil cover of the territory has undergone a co-evolutionary path closely related to plants, fauna, microorganisms and climatic factors. 32 soil types are widespread in the Greater Caucasus region, mainly 16 in forest and high mountain landscapes. In forested areas, mainly meadow-forest, typical brown mountain-forest, grassy carbonate mountain forest, typical brown mountain-forest, etc. soils are widespread. Soils vary according to landscape types. In the tugai forests of the territory, mainly washed and carbonate (tugai) meadow-forest soils are widespread. In the low mountain-forest landscapes of the territory at altitudes of 500–600 m and 1000–1200

m above sea level, brown soils are widespread depending on the exposure. In the middle mountain landscapes of the area at altitudes of 1000–1500 m above sea level, mainly brown mountain-forest, sedimentary-carbonate mountain-forest, typical and washed mountain-forest soils are widespread. In the high mountain landscapes of the area at intervals of 1800–2000 m and 3200–3400 m above sea level, primary and partially peaty mountain-meadow, grassy mountain-meadow, steppe mountain-meadow, in some places black soil-like soils, bare rocks, and clayey rocks are widespread.

3.5. Landscape diversity of the territory.

Respublika ərazisində təsvir edilmiş ümumi landşaftların 54%-i Böyük Qafqazın payına düşür. Böyük Qafqaz təbii vilayəti 2 landşaft sinifi, 2 yarımsinif, 8 landşaft tipi, 18 landşaft cinsi, 173 landşaft növünə bölünür. Tədqiqat ərazilərinin hüdudlarında isə 7 landşaft tipi üzrə 97 landşaft növünə rast gəlinir. Tədqiqa edilən ərazilər burada mövcud olan 5 landşaft tipini əhatə edir (Soyuq mülayim rütubətli iqlimə malik yüksək dağ landşaftları; Rütubətli və mülayim-rütubətli iqlimə malik dağ-çəmən landşaftları; Mülayim-rütubətli dağ-meşə landşaftları; Mülayim quru arid meşələr və arid dağ-meşə landşaftları; Mülayim-rütubətli iqlimə malik orta və alçaq dağlığın landşaftları)

3.6. Geochronological evolution of the biological diversity of the territory.

The Greater Caucasus has a very long and complex history of development from a geological point of view. The end of the Mesozoic - Cenozoic periods saw serious changes in the territory of the present Greater Caucasus. During this period, dry areas were formed in the western part of the Greater Caucasus. As a result, radical changes occurred in the flora and vegetation of the dry areas. In the Middle Miocene, the Caucasian Archipelago began to form. At this time, the Greater Caucasus was in the form of an island. The

elimination of the ancient Cenozoic flora was completed, and the core of the modern flora was formed[27].

CHAPTER IV
FLORA OF FOREST LANDSCAPES OF THE GREATER CAUCASUS

4.1. Main types of forest spread on the territory.

In Azerbaijan, forests descend to sea level in 2 places. Yalama forests in the north and Hirkan forests in the south. This is mainly due to the annual amount of precipitation (1000 mm and more). Forest formations with a rich typological composition are found in the forest landscapes of the Greater Caucasus. However, the species composition of these forest types is not very complex and is represented by 2-3 dominant species.

The forest landscapes of the Greater Caucasus and their plant diversity are mainly intrazonal tugai forests, plain and mountain forests. Tuqay forests stretch along the river banks in a narrow strip. Here several forest types replace each other. In the plain forests of the Ganikh-Haftaran valley, at altitudes of 160-170 m above sea level, *Quercus robur* subsp. *pedunculiflora* (*Quercus longipes*), *Q.castaneifolia* C.A.Mey., *Alnus glutinosa* subsp. *barbata* (C.A.Mey) Yalt., *Fagus orientalis* Lipsky., *Pterocarya fraxinifolia* (Poir.) Spach., *Populus alba* L. (*Populus hybrida* M.Bieb.), *Acer velutinum* Boiss., *Ulmus minor* Mill., *Carpinus betulus* L. (*C.caucasica* Gross.) and *Pistacia atlantica* Desf.. (*P.mutica* Fisch. & C.A.Mey.) are found. On the banks of the Mazymchay River, a population of *Parrotia persica* C.A.Mey is widespread. The middle layer consists mainly of, *Corylus avellana* L., *Punica granatum* L., *Crataegus germanica* (L.) Kuntze *(Mespilus germanica* L.), *Cornus mas* L., *Prunus divaricata* A.Sav., *P.spinosa* L., *Vitis vinifera* L.

[27] Тагиева, Е.Н. Некоторые аспекты эволюции растительности Кавказа в палеоцене и эоцене // – Баку: Известия НАН Азербайджана, Серия наук о Земле, –2006. № 3, – с.114-118.

(*V.silvestris* Roth.), *Crataegus pentagyna* Waldst. & Kit. ex Willd., *Euonymus europaeus* L., *Juniperus polycarpos* K.Koch., *Ligustrum vulgare* L., *Paliurus spina-christi* Mill., *Convolvulus fruticosus* Pall.[28], *Zosima absinthifolia* (Vent.) Link.[29] and other shrub species, and lianas *Hedera caucasigena* Pojark., *Smilax excelsa* L.. The main vegetation of the plain forests of the Samur-Davachi Lowland is *Quercus robur* subsp. *pedunculiflora (Q.pedunculiflora), Alnus glutinosa* subsp. *barbata, Pterocarya fraxinifolia* and others., mixed, mainly mountainous, lowland forest and forest-steppe vegetation with shrubs. In some places, the forests consist of oak species Quercus robur subsp. pedunculiflora, Q.pubescens, and in some places a mixture of oak and hornbeam (Carpinus betulus). Populus canescens (Aiton) Sm., P.nigra L. are more common in humid areas, and A.glutinosa subsp. barbata in swampy areas. In a small area, Ulmus minor forests are found. Among them are Acer campestre L., Acer cappadocicum subsp. cappadocicum (A. laetum C.A.Mey.), Crataegus germanica, Crataegus pentagyna, C.orientalis Pall. ex M.Bieb., Cornus sanguinea subsp. australis (C.A.Mey.) Jáv. (Swida australis Pojark. ex Grossh.), Fraxinus excelsior L., Prunus divaricata, Malus sylvestris (L.) Mill., Torminalis glaberrima (Gand.) Sennikov & Kurtto (Sorbus torminalis (L.) Crantz.), Cydonia oblonga Mill., Pyrus salicifolia Balb., etc. There are also trees and shrubs. Among the climbing plants, the following species are found: Hedera caucasigena, Humulus lupulus L., Smilax excelsa Duhamel., Periploca graeca L., etc..Tugay forests exist in relatively large patches on the banks of the Kura River, in the Garayazi depression, on the banks of the Khachinchay River, on the banks of the Ganikh (Alazan), Gabyrri (Iori), Ayrichay and Turyanchay rivers, and in small fragments on the banks of the Gozluchay, Velvelachai,

[28] Каримов, В. Новые для флоры Кавказа виды сосудистых растений из Азербайджана / В. Каримов, Э. Юсифов, Р. Муртазалиев // Ботанический журнал, – С.Пт.: – 2016. №5, – с. 592-594.

[29] Yusifov, E.F. Phytosenological study of *Zosima absinthifolia* (Vent.) Link. in Azerbaijan // Ninth International Symposium "Steppes of Northern Eurasia". IOP Conf. Series: Earth and Environmental Science. – 2021. v. 817, – p. 75-80.

Agsuchay, Goychay and Gargarchay rivers. Willow forests are mainly distributed along the banks of the Kura River. There are *Salix caprea* L., *S.cinerea* L. (*S. phlomoides* M. Bieb.), *S.purpurea* L., *S.triandra* L., *S.alba* L., *Salix* × *fragilis* f. *vitellina* (L.) I.V.Belyaeva *(S.australior* Andersson), *S.pentandra* L. species. As you move away from the coast, oak *(Quercus robur* subsp. *pedunculiflora)* is added to the elm species. At the end of the zone, gum tree *(Pistacia atlantica)* is spread. The main background species of dendroflora of Tugai forests are *Populus alba* L. (*P.hybrida* M.Bieb.), *P.nigra* L., *Ulmus minor* subsp. *minor* (*U.syberosa* Mill.; *U.foliacea* Gilib.), *Quercus robur* subsp. *pedunculiflora* (*Q.longipes* Steven.), *P. fraxinifolia*., *Salix caprea*, *S.cinerea, S. purpurea, S. triandra* L., *S. alba*, *Salix* × *fragilis f. vitellina*, *Morus alba* L, *Elaeagnus angustifolia* L. (*E.caspica* (Sosn.) Grossh.), *Pyrus salicifolia* species. Dendrological strip *Pistacia mutica* Fisch. & C.A. May. is bounded by. The shrub plants of the area are mainly *Crataegus rhipidophylla, Punica granatum, Crataegus germanica, Berberis iberica* (DC.) Steven, *Ligustrum vulgare* L., *Cornus mas* L., *C.sanguinea* subsp. *australis, Hippophae rhamnoides, Tamarix ramosissima* Ledeb., *T. hohenackeri* Bunge, *Paliurus spina-christi* etc. Here, lianas such as *Hedera colchica* (K.Koch) K.Koch (*H.caucasica* Pojark.), *V.vinifera, Smilax exelsa* Duhal., *Periploca graeca, Clematis vitalba* L. *P.alba* is found on the river banks that are not subject to anthropogenic impact, and Pistacia mutica and *Quercus* sp. are found on the borders.

There are also different aspects here. For example, in the Türyanchay tugai forests, Quercus petraea subsp. polycarpa (Schur) Soó (Q.iberica Steven ex M.Bieb.), Cotinus coggygria, various willow and juniper species are found. The coastal dendroflora of the area where the Velvelachai and Jimichay rivers meet is formed by dense Hippophae rhamnoides thickets. On the banks of the Tugchay and Dizavar rivers, remnants of unique tugai forests in the form of small patches have remained. The main element of these forests is Populus euphratica Olivier. Ulmus minor, Ficus carica L., Punica granatum, Cotoneaster saxatilis Pojark, Rhamnus erythroxyloides subsp. erythroxyloides (R.pallasii Fisch. & C.A.Mey.), Tamarix sp.,

Ephedra sp., Prunus microcarpa C.A.Mey., Paliurus spina-christi species are widespread here[30]. As a result of the conducted research, about 70 old trees of the plane, oak, black locust, poplar, and gum genera were recorded in Azerbaijan, and their dendrological parameters were measured[31].

4.2. Flora diversity of forest landscapes of the territory.

Based on long-term research and literature materials, 672 plant species have been identified in the forest landscapes of the Greater Caucasus within the Azerbaijani borders. Within the Caucasus ecoregion, the taxonomic structure of the flora diversity of the forest landscapes of the Greater Caucasus is divided into several groups according to their intra-regional distribution area (Table 1).

Table 1.

Taxonomic structure of flora diversity of forest landscapes

№	Class	Familia	Genera	Species
1.	Lycopodiopsida	1	1	1
2.	Equisetopsida	1	1	2
3.	Polypodiopsida	9	13	25
4.	Pinopsida	3	3	9
5.	Liliopsida (Monocotyledones)	15	59	142
6.	Magnoliopsida (Dicotyledones)	61	231	492
Landscape total:		**90**	**308**	**672**

Some of these are species with a wide range and exceed the boundaries of the ecoregion. These species are irregularly distributed across different plant classes. 516 species found in the area have a wide range. The families Asteraceae (61 species), Rosaceae (60

[30] Юсифов, Э.Ф. Геоботанический анализ тугайных лесов степной зоны Азербайджана // Степи Северной Евразии: материалы X международного симпозиума, – Оренбург: ИС УрО РАН, – 2024. – с. 1531-1538.

[31] Təhməzov, B.H., Yusifov E.F., Əsədov K.S. Azərbaycanın bioloji təbiət abidələri / B.H.Təhməzov, E.F.Yusifov, K.S. Əsədov – Bakı: Adiloğlu, – 2004. – 568 s.

species), Orchidaceae (37 species), Apiaceae (30 species), Poaceae (31 species), Fabaceae (26 species), Lamiaceae (23 species), Caryophyllaceae (22 species) are the dominant families in development in the area[32]. There are sensitive families consisting of 1-2 species in the area. The extinction of these species ultimately means the extinction of an entire genus and family. Six genera of higher plants, three genera of monocotyledons, and 22 genera of dicotyledons are susceptible to this[33].

4.3. Endemism of flora diversity of forest landscapes of the territory.

The endemism of the flora of the forest landscapes of the Greater Caucasus is divided into macroendemics, Caucasian endemics (subendemics), South Caucasian endemics (euryendemics) and Azerbaijani endemics (stenoendemics). 156 species in the area are endemic species of various categories of the Caucasus ecoregion. The dominant families among endemic species are Asteraceae (22 species), Rosaceae (19 species), Apiaceae (12 species), Asparagaceae (8 species), Ranunculaceae (8 species), Caryophyllaceae (8 species), Caprifoliaceae (7 species). Endemic species are grouped into 5 groups according to their range (Table 2). According to these classifications, 114 species are macroendemic, 36 species are Caucasian endemic, and 6 species are South Caucasian endemic in the flora of the forest landscapes of the Greater Caucasus (Figure 2). One species described from the territory of the Ismayilli administrative region is a national endemic of Azerbaijan (Figure 3).

---

[32] Ibadullayeva, S. Rare and endangered species of Shahdag National Park (Azerbaijan) with special status / S. Ibadullayeva, E. Yusifov, A. Mustafayev // Biodiversity Journal, – 2023, 14 (3), – p. 449 - 458.

[33] Yusifov, E. Biodiversity, Biogeography and Endemism of the Forest and High Mountain Flora of the Azerbaijan part of Greater Caucasus. // Acta Botanica Caucasica, – 2024. v. 3. No1, – p. 47-58.

Table 2.

Distribution of the dominant families of endemism of forest landscapes by subregions.

Subendemiv areals	Total number of species	Number of endemic species within the family							
		Asteraceae	Rosaceae	Apiaceae	Caryophyllace	Ranunculacea	Asparagaceae	Caprifoliaceae	Liliaceae
Wide-ranging species	**516**	40	42	19	14	11	9	6	0
Endemic species	**156**	22	19	12	8	8	8	7	6
including:									
N.Caucasus, S.Caucasus, Iran, Turkey	61	7	5	6	2	5	4	5	-
N.Caucasus, S.Caucasus, Turkey	36	5	7	3	1	1	-	-	2
N.Caucasus, S.Caucasus, Iran	17	-	1	1	1	-	2	-	1
N.Caucasus, S.Caucasus	36	7	2	1	4	2	1	2	2
South Cauacsus	6	-	4	-	1	-	-	-	1
Endemic of Azerbaijan	1	-	-	-	-	-	1	-	-

4.4. Ecological Analysis of the flora of forest landscapes of the territory.

Forest ecosystems are relatively resistant systems to the risks of climate change. The main sources of risk for these landscapes are climate change, diseases, illegal livestock grazing, illegal economic activities (recreation, gravel production, transportation of forest land), and anthropogenic forest fires. Parasitic (Cuscuta L.) and semi-parasitic plants (*Viscum album* L., *Arceuthobium oxycedri* (DC) M.Bieb, etc.), insects, mainly coleopterans (long-nosed beetles, leaf beetles), hemiptera (beetles, mealybugs, armadillos, plant lice), and hymenopterans (sawflies) damage phytocenoses and weaken the immune system. Pathogenic fungi and bacteria transmitted and spread by insects (*Holcogaster fibulata*) cause serious damage to the

dendroflora of the area by causing various diseases (cancer, root rot, etc.) [34].

Figure 2. Caucasian endemics of forest landscapes: a– *Crocus adami* J. Gay.; b– *C.speciosus* M.Bieb.; c– *Helleborus orientalis* subsp. *orientalis;* d– *Inula grandiflora* Willd.; e– *Lilium monadelphum* Adams.; f – *Valeriana tiliifolia* Troickij..

[34] Yusifova, N.A., Mammadov, H.A., Yusifov, E.F. The first record of *Holcogaster fibulata* (Germar, 1831) in Caucasian fauna (Hemiptera: Pentatomidae) // The 5th International Scientific Conference Modern Sciense and Tecnology Innovations. Stockholm, Sweden, – 2020, – p. 272-274.

Figure 3. Endemic of Azerbaijan: *Eremurus azerbajdzhanicus* Kharkev.

The causative agents of plant diseases are mainly viruses, bacteria, parasitic and semi-parasitic plants. Insects also play a role here. In particular, bark beetles, wood mites, leafhoppers, long-whiskered beetles, etc. In addition to causing direct damage, they also infect trees with various bacteria and viruses. Illegal economic activity in forested areas has led to a sharp decline in tugai forests and changes in the structure of phytocenosis. As a result, the edificatory species of the tugai forest belt (*Populus* sp., *Crataegus* sp., *Pistacia mutica*) are destroyed and transformed into a jungle of blackberry and lingonberry bushes (Alazan-Ayrichay). Another important function of tugai forests is that they protect the banks of rivers from erosion. The tree species found in tugai forests have a high transpiration capacity and play an important ecological role by regulating the level and mineralization of groundwater. The

Euphrates poplar (*Populus euphratica* Olivier.) is on the verge of extinction due to the impact of anthropogenic factors (illegal gravel exploitation, grazing).Ərazinin nisbətən zəngin və inkişafda olan fəsilələrinin sayı 4-dür. Bu fəsilələr cinslərinin və növlərinin zənginliyi ilə seçilir: Asteraceae (38:61), Rosaceae (18:60), Orchidaceae (17:37), Poaceae (17:31), Fabaceae (11:26). Meşə landşaftlarında yaılmış birləpəli bitkilərin florada 1 və ya 2 növ ilə təmsil olunan 3 həssas fəsiləsi *(Apocynaceae, Dioscoreaceae, Smilacaceae, Melanthiaceae)* müəyyən edilib. 22 sensitive families of dicotyledons have been identified. These are the Araliaceae, Cornaceae, Hydrangeaceae, Viburnaceae, Ebenaceae, Balsaminaceae, Platanaceae, Juglandaceae, Hypericaceae, Cistaceae, Lythraceae, Nymphaeaceae, Ophioglossaceae, Paeoniaceae, Berberidaceae, Elaegnaceae, Urticaceae, Linaceae, Rutaceae, Convolvulaceae, Verbenaceae, Asphodelaceae families. Thus, the number of dominant families developing in the flora of the forest landscapes of the Greater Caucasus is 4, and the number of sensitive families is 22. 6 South Caucasus endemics and 1 Azerbaijan endemic are distributed in the area. *Lathyrus leptophyllus* M.Bieb. (Fabaceae), *Pyrus vsevolodovii* T.S.Heideman (Rosaceae), *Pinus eldarica* Medw. (Rosaceae), *Rosa alexeenkoi* Crep. Ex Juz. (Rosaceae), *R.sosnovskyi* Chrshan. (Rosaceae) are South Caucasus endemics.

CHAPTER V
FLORA OF ALPINE-SUBALPINE LANDSCAPES OF THE AREA.

5.1. Flora diversity of alpine-subalpine landscapes of the area.

In the Greater Caucasus, the subalpine zone covers altitudes of 1800-2000 m and 2500–2700 m, depending on the relief and climatic characteristics of the area and exposure, and the alpine zone covers altitudes in the intervals of 2500 m and 3000–3200 m, sometimes 3500 m. 663 species belonging to 64 families and 293 genera were

identified in the alpine-subalpine landscapes within the study areas. These species are unevenly distributed across classes (Table 3).

Table 3.

Taxonomic structure of flora diversity of alpine-subalpine landscapes

№	Class	Familia	Genera	Species
1.	Lycopodiopsida	1	1	1
2.	Equisetopsida	1	1	2
3.	Polypodiopsida	3	5	8
4.	Pinopsida	2	2	3
5.	Liliopsida (Monocotyledones)	11	54	114
6.	Magnoliopsida (Dicotyledones)	46	229	535
Landscape total:		**64**	**293**	**663**

Alpine carpets are plant communities with relatively poor plant diversity (mainly 15-30 species or less) in the form of small patches at altitudes of 2900-3500 m, at the upper limits of the alpine belt, around never-melting snow areas, in sunny and abundantly watered, stony-gravel areas. The families Asteraceae (108 species), Poaceae (49 species), Fabaceae (41 species) are the dominant families with the highest species diversity in the landscape. They constitute 30% of the total number of species found in alpine-subalpine landscapes. 22 families belonging to 5 classes, represented by 1-2 species in these landscapes, have been identified.

In ecotones where alpine landscapes transition to subnival landscapes, tundra-type alpine carpets are found in areas dominated by the mountain-tundra climate type (Figure 4.).

5.2. Endemism of Alpine-subalpine landscapes of the territory.

342 endemic species of different categories are distributed in the alpine-subalpine landscapes of the Greater Caucasus within the Azerbaijani borders (Figure 5.). According to the richness of endemic species, 6 dominant families are distinguished.

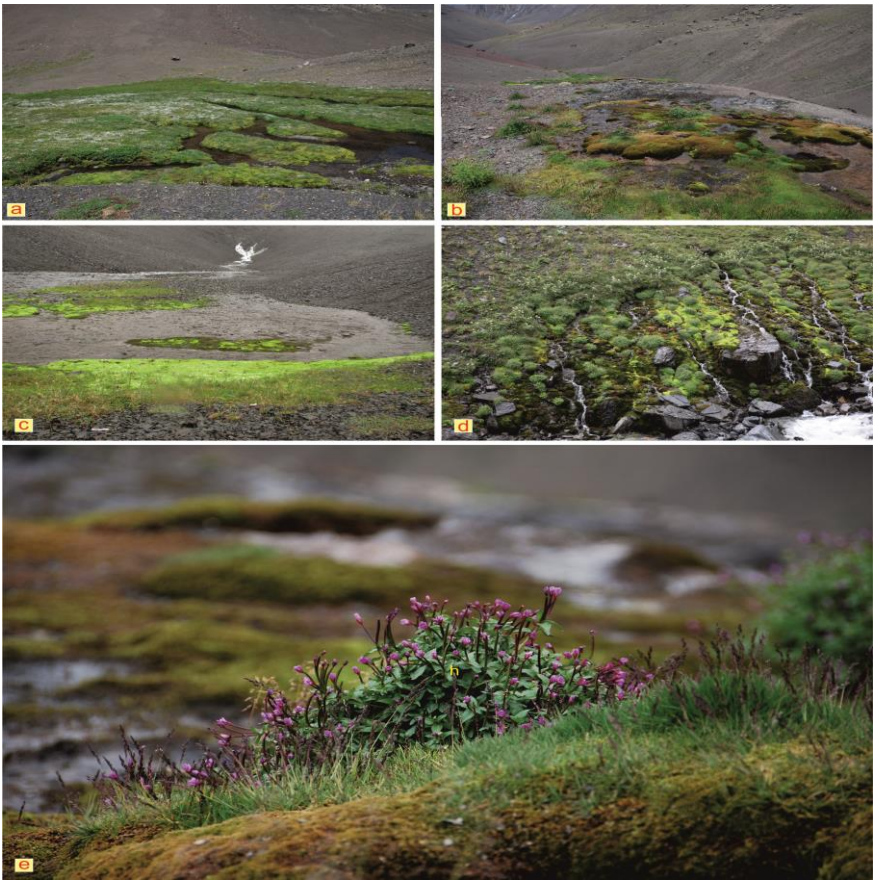

Figure 4. Alpine-tundra type meadows of the area ("alpine carper"): a – Shahyaylag Plateau (3500 m); b - the foot ofthe Bazaryurd Mountain; c – vicinity of the Tufangol Lake (3500 m); d – the sourse of the Yatigchay River (3200 m); e – tundra vegetation with *Epilobium anagallidifolium* Lam.

These are the families Asteraceae (55 species), Caryophyllaceae (25 species), Fabaceae (25 species), Campanulaceae (20 species), Apiaceae (21 species), Rosaceae (21 species), Brassicaceae (17 species), Lamiaceae (17 species) (Table 4.)

Figure 5. Subendemic species of the Greater Caucasus of Azerbaijan: a - *Galanthus lagodechianus* Kem.-Nath.; b– *Agasyllis latifolia* (M.Bieb.) Boiss.; c– *Psephellus paucilobus* (Trautv.) Boiss; d– *Campanula lezgina* (Alex.) Kolak. & Serdyuk.; e– *Cerastium kasbek* Parrot; f– *Betonica nivea* Steven.

Table 4.

Distribution of the dominant families of endemism of alpine-subalpine landscapes by subregions.

Subendemiv areals	Total number of species	Number of endemic species within the family							
		Asteraceae	Caryophyllaceae	Fabaceae	Campanulaceae	Apiaceae	Rosaceae	Brassicaceae	Lamiaceae
Wide-ranging species	**321**	51	13	22	2	8	18	9	19
Endemic species	**342**	55	25	25	20	21	21	17	17
including:									
N.Caucasus, S.Caucasus, Iran, Turkey	92	15	4	8	5	7	6	5	5
N.Caucasus, S.Caucasus, Turkey	92	18	5	5	7	2	7	5	2
N.Caucasus, S.Caucasus, Iran	10	2	-	-	-	1	-	1	-
N.Caucasus, S.Caucasus	141	20	16	11	8	11	8	6	10
South Caucasus	2	-	-	-	-	-	-	-	-
Azerbaijan	**4**	**-**	**-**	**1**	**-**	**-**	**-**	**-**	**2**

The endemic species found in the area can be conditionally divided into the Caucasus ecoregion (North Caucasus, South Caucasus, Iran, Turkey), Iranian (North Caucasus, South Caucasus, Iran) and Turanian (North Caucasus, South Caucasus and Turkey) subendemics. As can be seen from Table 4, the leadership in terms of absolute endemism belongs to the family Asteraceae (55 endemic species).

The Apiaceae and Campanulaceae families are the leaders in terms of endemism of the general species in the landscape. 21 out of 29 species of the Apiaceae family, and 20 out of 22 species of the Campanulaceae family are endemic species of various statuses. As can be seen, the maximum number of endemic species falls on the

entire Caucasus (North and South Caucasus) region (141 endemic species). 2 species found in the mentioned landscape are endemic to the South Caucasus. These are Euphrasia daghestanica Juz. and *Asperula azerbaidjanica* Mam, Shach & Velib. *A.latifolia* (M.Bieb.) Boiss., *Astrantia biebersteinii* Trautv., *Heracleum roseum* Steven, *H.sosnowskyi* Manden., *Nonea alpestris* G.Don, *Sobolewskia caucasica* M.Bieb., *Campanula caucasica* Kharadze, *C.lezgina, Psephellus paucilobus* (Trautv.) Boiss and other species are endemic to the Greater Caucasus. The ranges of other species have most likely expanded as a result of horizontal migrations. This indicates that the Caucasus, especially the vicinity of Bazarduzu, is the center of speciation (Figure 6.). 2 species widespread in the area are endemic to the South Caucasus. These are *Euphrasia daghestanica* (Orobanchaceae) and *Asperula azerbaidjanica* (Rubiaceae). As can be seen from Table 4, there are 4 national endemics in the flora of the alpine-subalpine landscapes of the Greater Caucasus. *Astragalus kubensis* Grossh., *Erodium schemachense* Grossh., *Nepeta longituba* Pojark., *Thymus karjaginii* Grossh. are Azerbaijani endemics of the alpine-subalpine landscapes of the Greater Caucasus.

The Apiaceae and Campanulaceae families are the leaders in terms of endemism of the general species in the landscape. 21 out of 29 species of the Apiaceae family, and 20 out of 22 species of the Campanulaceae family are endemic species of various statuses. As can be seen, the maximum number of endemic species falls on the entire Caucasus (North and South Caucasus) region (141 endemic species).

2 species found in the mentioned landscape are endemic to the South Caucasus. These are *Euphrasia daghestanica* Juz. and *Asperula azerbaidjanica* Mam, Shach & Velib. A.latifolia (M.Bieb.) Boiss., Astrantia biebersteinii Trautv., Heracleum roseum Steven, *H.sosnowskyi* Manden., *Nonea alpestris* G.Don, *Sobolewskia caucasica* M.Bieb., *Campanula caucasica* Kharadze, *C.lezgina, Psephellus paucilobus* (Trautv.) Boiss and other species are endemic to the Greater Caucasus. The ranges of other species have most likely expanded as a result of horizontal migrations.

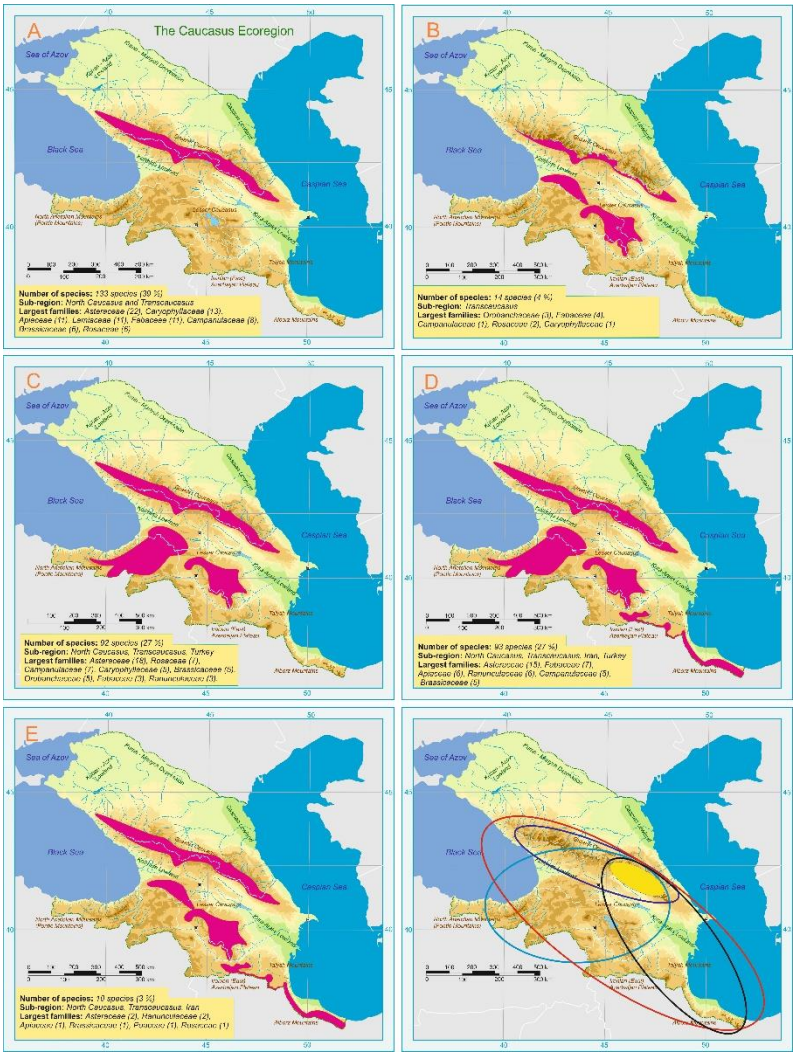

Figure 6. Main breeding centers and areas of endemism in alpine-subalpine landscapes within the boundaries of the study areas

This indicates that the Caucasus, especially the vicinity of Bazarduzu, is the center of speciation (Figure 6.). 2 species widespread in the area are endemic to the South Caucasus. These are

Euphrasia daghestanica (Orobanchaceae) and *Asperula azerbaidjanica* (Rubiaceae). As can be seen from Table 4, there are 4 national endemics in the flora of the alpine-subalpine landscapes of the Greater Caucasus. *Astragalus kubensis* Grossh., *Erodium schemachense* Grossh., *Nepeta longituba* Pojark., *Thymus karjaginii* Grossh. are Azerbaijani endemics of the alpine-subalpine landscapes of the Greater Caucasus.

5.3. The impact of climate changes on the Alpine-subalpine flora of the area.

Climatic conditions and the duration of the vegetation period vary depending on altitude. As altitude increases, the decrease in the average annual temperature leads to a reduction in the vegetation period. However, global warming increases this period in high mountainous areas.

.The rapid melting of glaciers accelerates this process even more. This, in turn, causes structural changes in the vegetation of the area. While the increase in temperature creates favorable conditions for thermophilic species in the area, it plays the role of a limiting factor for cryophyte and mesophyte species.

The study is devoted to monitoring and analyzing changes in the distribution of vegetation in the alpine and subalpine landscapes of Azerbaijan as a result of the impact of global warming. The increase in temperature will lead to a gradual increase in the number of thermophilic species in the area. The gradual decrease in precipitation, including snow cover, will limit the living conditions of cryophyte and mesophyte species. Because these plants will be deprived of the snow cover that protects them from frost, sharp temperature fluctuations, strong winds in the cold winter season, and is necessary for water supply in the spring season. Some cryophyte species will become extinct due to their inability to adapt to the environment, while others will try to settle in higher areas. However, the upper limit of alpine landscapes and subnival areas consist of mountain rocks. The process of soil formation from mountain rocks requires a long period of time. The new conditions will be

unfavorable for alpine species accustomed to a well-developed turf soil layer, rich in humus. As a result, *Archanthemis marschalliana* subsp. *sosnovskyana* (Grierson) Lo Presti & Oberpr. (*A.sosnovskyana* Fed.), *Campanula petrophila* Rupr., *Dichodon cerastoides* (L.) Rchb. (*Cerastium cerastioides* (L) Britton), *Cerastium kasbek, C.multiflorum* C.A.Mey., *Jurinea moschus* (Hablitz) Bobrov (*Jurinella subacaulis* (Fisch. & C.A.Mey.) Iljin), *Lamium tomentosum* Willd., *Pseudocherleria inamoena* (C.A.Mey.) Dillenb. & Kadereit (*Minuartia inamoena* (C.A.Mey.) Woronow ex Grossh.), *Pseudocherleria imbricata* (C.A.Mey.) Dillenb. & Kadereit (*Minuartia imbricata* (C.A.Mey.) Woronow), *Myosotis alpestris* F.W.Schmidt, *Pseudovesicaria digitata* (C.A.Mey.) Rupr., *Saxifraga flagellaris* Willd., *Scrophularia minima* M.Bieb., *Symphyoloma graveolens* C.A.Mey., *Taraxacum stevenii* (Spreng.) DC., *Phedimus stevenianus* (Rouy & E.G.Camus) 't Hart (*Sedum stevenianum* Rouy & E.G.Camus), *Silene humilis* C.A.Mey., S.lacera (Steven) Sims, *Tephroseris integrifolia* subsp. primulifolia (Cufod.) Greuter (*Senecio karjaginii* Sofieva), *Turanecio taraxacifolius* (M.Bieb.) Hamzaoğlu (*S.taraxacifolius* (M.Bieb.) DC.), *Viola minuta* M.Bieb., *Ziziphora puschkinii* Adams (*Ziziphora karjaginii* Ter-Chatsch) etc. will be at risk. Plants with stolon-forming shoots such as *Saxifraga flagellaris* Willd., *Lathyrus formosus* (Steven) Kenicer (*Vavilovia formosa* (Steven) Fed.; *V.aucheri* Fed.) etc. will easily adapt to the new environment. The increase in the growing season as a result of warming poses risks for alpine plants adapted to a short growing season.

5.4. Ecological analysis of subnival landscapes of the territory.

The number of relatively rich and developing families of the area is 4. These families are distinguished by the richness of their genera and species: Asteraceae (47:108), Poaceae (26:50), Fabaceae (11:41), Rosaceae (12:39). 21 families distributed here (Equisetaceae, Ophioglossaceae, Pteridaceae, Taxaceae, Melanthiaceae, Potamogetonaceae, Aceraceae, Amaranthaceae,

Linaceae, Celastraceae, Euphorbiaceae, Grossulariaceae, Fagaceae, Haloragaceae, Hypericaceae, Malvaceae, Plumbaginaceae, Polygalaceae, Resedaceae, Urticaceae, Apocynaceae) are sensitive families of the area and are represented either by 1-2 species, or have limited or sparse populations. Thus, the number of developing, dominant families in the flora of the alpine-subalpine landscapes of the Greater Caucasus is 4, and the number of sensitive families is 21. Two South Caucasus and five Azerbaijani endemics are distributed in the area.

CHAPTER VI
FLORA OF SUBNIVAL LANDSCAPES OF THE TERRITORY

6.1. Flora diversity of subnival landscapes of the territory.

The subnival zone is distinguished by extreme environmental conditions. It is characterized by low partial pressures of oxygen and carbon dioxide, high solar radiation, high temperature differences between day and night, a large number of frosty days during the growing season, and strong winds. Over the past 20 years, the melting of glaciers in Azerbaijan has led to a sharp change in the climatic conditions of subnival organisms, their warming. The rate of adaptation of plants to new climatic conditions is extremely slow. In this regard, subnival vegetation is under high abiotic pressure. Another difference between the subnival zone of the Greater Caucasus and the alpine zone is that the amount of precipitation here decreases sharply. The main reason for this is the position of the eastern part of the Greater Caucasus relative to the equator. In the western part of the Greater Caucasus, the upper limit of forests rises to 3200–3700 m, and in the Pamir-Himalayan regions it rises to 6000 m. The first case is due to precipitation brought by humid winds coming from the Black Sea. The second case is due to the proximity of the mentioned area to the equator. The climatic characteristics of our area (mainly solar radiation) form the circulation of humid air masses at altitudes up to 2500-3000 m. At altitudes above this,

precipitation decreases sharply. It is this factor that plays the role of a limiting factor at those altitudes.

In the Greater Caucasus, high-mountainous subnival landscapes mainly cover areas from 3200-3500 m to 4000 m altitude, depending on the relief and climatic features of the area. Here, the average temperature of the warmest month is 0–5 0C and below, the temperature of the coldest month is – 15 0C and below, and the average annual air temperature is below 0 0C. The average annual amount of precipitation is 900-1200 mm.

The unique configuration of the mountains causes precipitation due to the retention of humid air currents. As a result, a unique weather and temperature regime is formed in the area. This, in turn, forms unique climatic conditions and high endemism. The landscape of the area belongs to the nival and subnival landscapes of the high mountains (3000–4000 m) with a cold, temperate-humid climate. Here, mainly petrophytes: plants of rock substrates (chasmophytes), avalanche and moraine vegetation prevail.

In the subnival landscapes within the study areas, 131 species belonging to 29 families and 82 genera were identified. These species were unevenly distributed across classes (Table 5). The families Asteraceae (23 species), Poaceae (20 species), and Caryophyllaceae (12 species) had the highest species diversity across the landscape. As the altitude increased, the families Asteraceae and Poaceae maintained their dominance, while the family Fabaceae gave way to the family Caryophyllaceae.

Table 5.

Distribution of flora diversity of subnival landscapes by plant classes

№	Class	Families	Genera	Species
1.	Polypodiopsida	1	1	1
2.	Liliopsida (Monocotyledones)	3	14	20
3.	Magnoliopsida (Dicotyledones)	25	67	110
Landscape total:		**29**	**82**	**131**

These species constitute 43% of the total number of species found in the subnival landscape41. Of the 131 plant species found in

the area, 47 species are widespread, and 84 species are endemic species of various categories spread within the Caucasus ecoregion. Of these, 124 species belong to the Dicotyledons class, 7 species belong to the Monocotyledons class.

Lamium tomentosum, Nepeta supina Steven., Myosotis alpestris, Senecio karjaginii species are found on the avalanche debris of clay shales in the valley areas. *Alopecurus dasyanthus* Trautv., *Silene humilis*, S.lacera, *P.digitata* species are found on rocks, on stony and gravelly slopes, and in moraines. *Taraxacum porphyranthum* Boiss., *Tripleurospermum caucasicum* (Willd.) Hayek, *Senecio taraxacifolius* M.Bieb. (DC), *Erigeron alpinus, Scrophularia minima*, and *Gagea glacialis* are common in plain areas.

6.2. Endemism of subnival landscapes of the territory.

83 endemic species have been identified in the regional landscapes (Table 6). All species encountered belong to the classes Liliopsida and Magnoliopsida. These species are irregularly distributed in the mentioned classes. 7 species were identified in 2 families belonging to the Liliopsida class. The representatives of the Magnoliopsida class are relatively numerous and consist of 77 species. Among the endemic species, 45 species are distributed in the North Caucasus, South Caucasus, Turkey and Iran.[35]. 37 species of them are Caucasian endemics of the region or subendemic species of Azerbaijan. These are *Melica minor* Hack. ex Boiss., *Chaerophyllum kiapazi* M.Bieb., *S.graveolens, Psephellus caucasicus* (Sosn.) Geuter., *Archanthemis marshalliana* subsp. *sosnovskyana*, *Kemulariella rosea* (M.Bieb. ex Steven) Tamamsch., *Senecio leucanthemifolius* subsp. *caucasicus, Taraxacum confusum* Schischk., *T.stevenii* (Spreng.) DC., *Trigonocaryum involucratum* (Steven) Kusn., *Noccaea germanii* Al-Shehbaz (*Eunomia*

[35] Yusifov, E.F., Ibadullayeva, S.J. The common sub-endemic plant species of Azerbaijan and Turkey found in alpine-subalpine and subnival belts // Second bilateral workshop on science between Dokuz Eylül University and Azerbaijan Academy of Sciences, – 18 november, – 2022, – p. 9.

rotundifolia C.A.Mey.), *P.digitata* (C.A.Mey.) Rupr. etc. are species[36].

Table 6.

Distribution of the dominant families of endemism of subnival Landscapes by subregions.

Subendemiv areals	Total number of species	Number of endemic species within the family							
		Asteraceae	Poaceae	Caryophyllaceae	Saxifragaceae	Brassicaceae	Rosaceae	Ranunculaceae	Apiaceae
Wide-ranging species	**48**	8	10	1	5	2	4	2	-
Endemic species	**83**	23	15	12	7	7	6	6	5
including									
N.Caucasus, S.Caucasus	**37**	8	1	6	1	2	-	2	2
N.Caucasus, S.Caucasus, Turkey	**25**	5	-	3	1	2	1	-	-
N.Caucasus, S.Caucasus, Iran, Turkey	**20**	2	3	2	-	1	1	2	3
N.Caucasus, S.Caucasus, Iran	**1**	-	1	-	-	-	-	-	-

The 3 families found in the area - Asteraceae (23 species), Poaceae (20 species), Caryophyllaceae (12 species) - are the richest and most developing families with the highest species diversity in the landscape. As the altitude increases, the families Asteraceae and Poaceae maintain their dominance, while the family Fabaceae gives way to the family Caryophyllaceae. Saxifraga L. (Saxifragaceae; 7 species), Anthemis L. (Asteraceae, 5 species), Senecio L.

[36] Yusifov, E.F. Ecological Analyses of Subnival Vegetation of Azerbaijan in the Context of Climate Change // Khazar Journal of Science and Technology, – v. 6, – 2022. №1, – p. 5-16.

(Asteraceae, 4 species), Taraxacum L. (Asteraceae, 4 species), Cerastium L. (Caryophyllaceae, 4 species), Cerastium L. (Caryophyllaceae, 4 species), Minuartia L. (Caryophyllaceae, 4 species) are relatively rich plant genera found in subnival landscapes. The 13 families distributed here are represented by 1 or 2 species. These are the families Aspleniaceae, Juncaceae, Ericaceae, Fabaceae, Geraniaceae, Liliaceae, Onagraceae, Orobanchaceae, Papaveraceae, Primulaceae, Scrophullariaceae, Valerianaceae, Violaceae. Thus, the number of dominant families developing in the flora of the subnival landscapes of the Greater Caucasus is 3, and the number of sensitive families is 13. There are 37 common Caucasian endemics in the area.

6.3. Ecological analysis of subnival landscapes of the territory.

Subnival landscapes are glacial deposits. The recent rapid melting of glaciers has disrupted the thermal regime of the area. As these species move uphill following the colder climate, their ranges and populations are decreasing. Since the narrow-range, cold-loving species in subnival landscapes are spread on peaks and lack alternative habitats, they are at high risk. Global warming poses great risks to small-scale species that are distributed in fragments. Seven species (Alopecurus dasyanthus, Nepeta supina Steven., Symphyoloma graveolens, Anthemis cretica subsp. iberica Grierson (A.iberica M.Bieb.), Saxifraga sibirica L. (S.mollis), Pseudobetckea caucasica (Boiss.) Lincz.) distributed at the upper limit of the subnival are under particular threat. Water scarcity will also pose risks to these species. The increase in the growing season leads to the spread of thermophytic species and cereals here. Thus, petrophyte plants found in subnival landscapes have adapted to the conditions of the stony-gravel substrate here. These plants are characterized by a special eco-biomorphological adaptation. They spread on the surface of gravelly deposits and have a long root system. They develop under the influence of gravity, when soil masses move down the slope. Each deposit here has its own unique vegetation. Plant formations vary depending on historical conditions, as well as the exposure of

the slopes, the shape of the relief, and the abiotic and ecological conditions of the habitat.

The plants of the area that are affected by gravity are: *Anthemis caucasica* Adam., *A.sosnovskyana*, *Cirsium macrocephalum* C.A.Mey., *C.obvallatum* (M.Bieb.), *Erigeron unoflorus*, *Senecio sosnowskyi*, *Cynoglossum holosericeum*, *Myosotis alpestris*, *Nonea alpestris*, *N.daghestanica* Kusn, *N.versicolor*, *T.involucratum*, *Silene humilis*, *S.lacera*, *Sedum stevenianum*, *S.tenellum*, *Sempervivum caucasicum*, *Lathyrus formosus* (Steven) Kenicer, *Lamium tomentosum*, *Thymus nummularius* M.Bieb., *Corydalis alpestris* C.A.Mey., *Delphinium caucasicum*, *R.arachnoideus* və s. Stabil, düzən çınqıllıqlarda rast gəlinən bitkilər *S.sosnowskyi*, *Taraxacum stevenii*, *P.digitata*, *Nepeta supina*, *Kemulariella rosea*, *Cardamine uliginosa*, *Cerastium multiflorum*, *S Symphyoloma graveolens*, *Chamaesciadium acaule* (M,Bieb,) Boiss.. The vegetation of subnival landscapes can be conditionally divided into 3 groups according to species composition: 1. Found only in subnival landscapes; 2. Found in subnival and alpine landscapes; 3. Plants found in landscapes of the subalpine, alpine and subnival zones. In the context of climate change, the risk levels of these plants are different. As the climate of the country warms, these species try to settle higher. That is, the ranges of the second and third groups of species are sharply narrowing. Pure subnival species at the highest altitudes (*Alopecurus dasyanthus*, *Nepeta supina*, *S.graveolens*, *Anthemis iberica*, *Saxifraga sibirica* L. (*S.mollis* Sm.*)*, *P.caucasica*) is at greater risk.

CHAPTER VII
ECOLOGICAL ANALYSIS OF THE FLORA OF HIGH MOUNTAIN LANDSCAPES OF THE AREA

7.1. Dominant, stable and sensitive taxa of the territorial flora.

If we look at the rich families represented in forest, alpine-subalpine and subnival landscapes and the sensitive families, it is

clear that the families Poaceae and Asteraceae dominate in all landscapes. In subalpine-alpine-subnival landscapes, the families Fabaceae and Rosaceae compete with them (Table 7).

Table 7.

Dominant and vulnerable families of the flora of the forest and high mountain landscapes of the area

Landscapes	Dominant families	Vulnerable families
Subnival 3:13	Poaceae, Asteracia, Caryophyllaceae	Aspleniaceae, Ericaceae, Fabaceae, Juncaceae, Geraniaceae, Liliaceae, Onagraceae, Orobanchaceae, Papaveraceae, Primulaceae, Scrophullariaceae, Valerianaceae, Violaceae
Alpine-subalpine 4:21	Poaceae, Asteraceae, Fabaceae, Rosaceae	Aceraceae, Amaranthaceae, Apocynaceae, Celastraceae, Equisetaceae, Euphorbiaceae, Fagaceae, Hypericaceae, Grossulariaceae, Haloragaceae, Linaceae, Malvaceae, Melanthiaceae, Ophioglossaceae, Potamogetonaceae, Pteridaceae, Plumbaginaceae, Polygalaceae, Resedaceae, Taxaceae, Urticaceae
Forest 5:22	Poaceae, Orchidaceae, Asteraceae, Fabaceae, Rosaceae,	Araliaceae, Asphodelaceae, Balsaminaceae, Berberidaceae, Cistaceae, Convolvulaceae, Cornaceae, Ebenaceae, Elaegnaceae, Hydrangeaceae, Hypericaceae, Juglandaceae, Linaceae, Lythraceae, Nymphaeaceae, Ophioglossaceae, Paeoniaceae, Urticaceae, Platanaceae, Rutaceae, Verbenaceae, Viburnaceae

Sensitive families can also occur due to the occupation of new territories by some species. The occupation of new territories is due to the influence of 2 factors: 1. As a result of global warming due to

climate change; 2. As a result of the ability of the species to reproduce, spread, occupy new territories and adapt to these territories. These results are also clearly visible in the diagrams (Figures 7, 8).

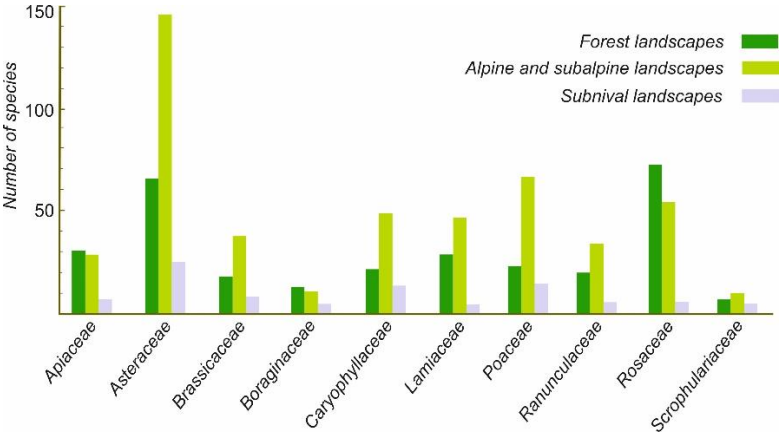

Figure 7. Families represented in each of the forest and highland landscapes of the study areas.

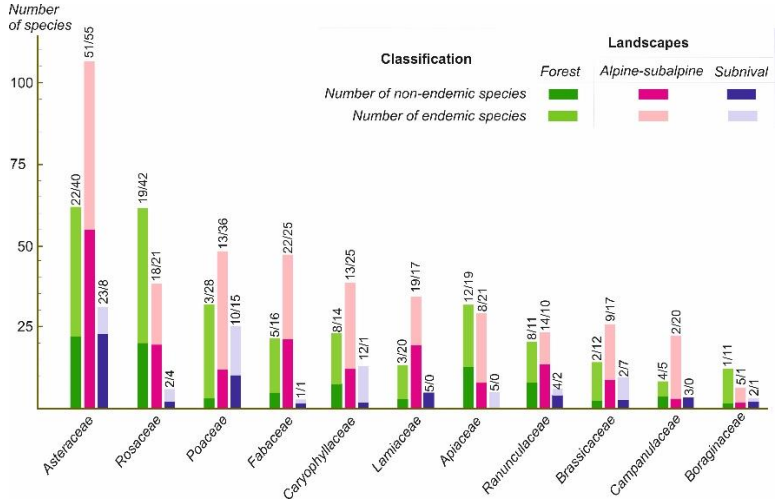

Figure 8. Distribution of the main families of the flora diversity of the forest and highland landscapes of the Greater Caucasus

7.2. Hypsometric dependence of flora and endemism of the territory.

Thus, out of 131 species found in subnival landscapes, 83 are endemic to the Greater Caucasus. This accounts for 63% of the species distributed in this area. The rich endemism of subnival landscapes also indicates that the area is a center of floristic speciation.

Endemism is a biogeographical concept and refers to plants found only in a specific area. When examining the factors affecting the endemism of the forest and high-mountain landscapes of the Greater Caucasus, the first noticeable dependence is that endemism is directly proportional to altitude (Figure 9.).

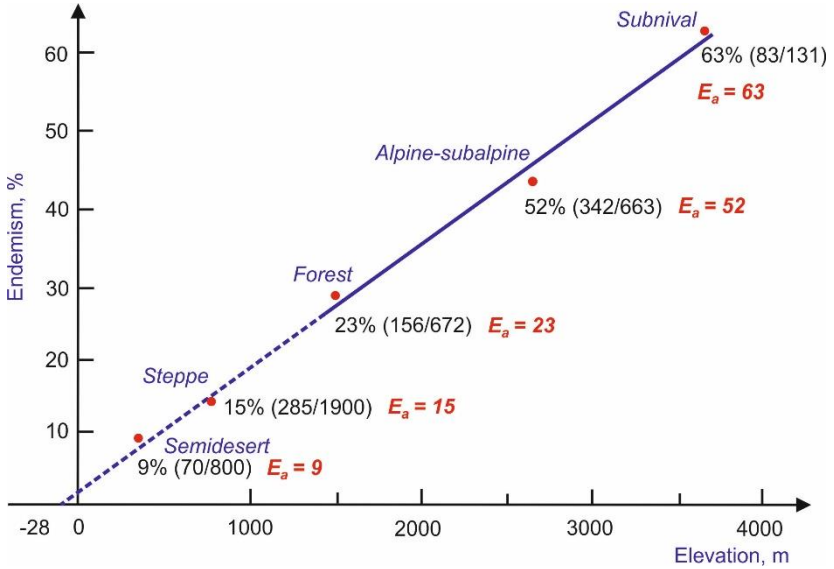

Figure 9. Hypsometric dependence of flora diversity and endemism and ecological autochthony index of the territory

.

The direct proportional dependence of endemism on altitude is also preserved in the landscapes of neighboring regions - Elburz-Zagros and the Alps. In high mountainous areas, the families Asteraceae, Caryophyllaceae, Brassicaceae, Apiaceae and Lamiaceae

are more widely represented in all landscapes, especially in the subnival landscape with extreme conditions. These species mainly have a taproot and branched root system. They are annual and perennial plants pollinated by insects. Among the mentioned families, the family Asteraceae dominates in terms of the number of petrophyte pioneer species. Table 8. lists the endemic flora species of various categories found in the Greater Caucasus in Azerbaijan.

Table 8.

The structure of the endemism of the flora of the forest and high-mountainous landscapes of the territory

Landcapes	Macro-endemics	Sub-endemics	Endemics of S.Caucasus	Total
Subnival	46	37	-	83
Alpine-subalpine	196	141	5	342
Forest	113	36	7	156
Total	**355**	**214**	**12**	**581**

Table 9. gives the distribution of flora endemism in the forest and high mountain landscapes of the Greater Caucasus by categories. As can be seen, Caucasian endemics dominate with 214 species.

The distribution of endemic families by landscapes and the ecological index vary by family (Table 10.). Some families are distributed in low and medium (forest-alpine) landscapes (marked in purple). Some are distributed only in middle landscapes (alpine-subalpine) (marked in yellow). Some families are distributed in middle and upper (alpine-subnival) landscapes (marked in blue). Families represented in all landscapes (green) are more stable taxa. The ecological index shows the stability of families in the face of climate change. Families represented in all landscapes are developing, stable families.

Table 9.

Böyük Qafqazın meşə və yüksək dağlıq landşaftları florası endemizminin kateqoriyası

№	Endemism categories	Caucasus ecoregion area	Number
1.	Wide-ranging species		885
2.	Endemic species		581
including:			
3.	I category	North Caucasus, South Caucasus, Iran, Turkey	175
4.	II category	North Caucasus, South Caucasus, Turkey	153
5.	III category	North Caucasus, South Caucasus, Iran	25
6.	Caucasian endemics	North Caucasus, South Caucasus	214
7.	Endemics of S.Caucasus	South Caucasus (Az.-Ir., Az.-Arm., Az.-Georg.)	8
8.	Azerbaijan endemics	Azerbaijan	6
Total			**1466**

Thus, their drift potential is high. Sensitive species manifest themselves in 2 forms. Families represented by one or two species and species that have been displaced from the lower reaches and settled only at high altitudes. Adaptation of high-altitude plants to new environments occurs in various ways. Dense hairs on the leaves (Asteraceae, Boraginaceae) and a waxy layer (Ranunculaceae) protect the leaves of plants from aggressive ultraviolet burns and weaken transpiration. Small and light, sail-shaped seeds are clearly manifested in aboriginal species belonging to the Brassicaceae family. Numerous small flowers (Asteraceae), reproduction by shoots (stolons) (Fabaceae) allow endemics to spread over large distances and conquer new territories. Budding reproduction and seed sails allow plants to spread in radical climatic conditions and allow endemics to spread to new territories. The adaptive traits acquired by subnival plant species (e.g. P. digitata) give them advantages in radical climatic conditions. The leafy leaves of the plant are intended to preserve the limited humidity in the area.

Table 10.

Distribution of endemic species on landscapes and its ecological

	Families	Belts			Ecological index
		Forest	Alp.-subalp.	Subnival	
1.	Amaryllaceae				6
2.	Apiaceae				9
3.	Asteraceae				9
4.	Betulaceae				3
5.	Boraginaceae				6
6.	Brassicaceae				9
7.	Campanulaceae				9
8.	Caryophyllaceae				9
9.	Crassulaceae				6
10.	Fabaceae				6
11.	Gentianaceae				6
12.	Geraniaceae				3
13.	Iridaceae				6
14.	Lamiaceae				9
15.	Liliaceae				6
16.	Orobanchaceae				3
17.	Poaceae				9
18.	Primulaceae				6
19.	Plantaginaceae				3
20.	Polygalaceae				3
21.	Ranunculaceae				9
22.	Salicaceae				3
23.	Saxifragaceae				6
24.	Scrophulariaceae				6
25.	Thymelaceae				3
26.	Valerinaceae				3
27.	Violaceae				3

The dense umbrella-shaped leaves protect the root system from high temperatures resulting from the influence of high radiation here.

The relatively long and developed root system helps to take advantage of the moisture in the deep layers of rocks.

Based on the obtained data, 5 Azerbaijani endemics were identified in the studied area based on the comparison of the local data obtained so far in the forest, alpine-subalpine and subnival landscapes within the Azerbaijani borders of the Greater Caucasus with the data of neighboring countries and international flora platforms (Table 11.).

Table 11.

Azerbaijan endemics found in forest and high mountain landscapes of the area

I.Asphodelaceae		
1.	*Eremurus azerbajdzhanicus*	On the dry southern slopes of 400-500 m altitude in the middle and lower mountain belt (Ismayıllı, Ivanovka)
II. Fabaceae		
2.	*Astragalus kubensis* Grossh.	Alpine meadows. Guba (Shahdag, Griz)
III. Geraniaceae		
3.	*Erodium schemachense* Grossh.	Subalpine belt, dry slopes (Guba, Adur villages)
IV. Lamiaceae		
4.	*Nepeta longituba* Pojark.	Subalpine meadows (Oguz, B.Dashagil villages)
5.	*Thymus karjaginii* Grossh.	Stony slopes, rock cracks (Guba, Gonagkend villages)

Thus, their drift potential is high. Sensitive species manifest themselves in 2 forms. Families represented by one or two species and species that have been displaced from the lower reaches and settled only at high altitudes. Adaptation of high-altitude plants to new environments occurs in various ways. Dense hairs on the leaves (Asteraceae, Boraginaceae) and a waxy layer (Ranunculaceae) protect the leaves of plants from aggressive ultraviolet burns and

weaken transpiration. Small and light, sail-shaped seeds are clearly manifested in aboriginal species belonging to the Brassicaceae family. Numerous small flowers (Asteraceae), reproduction by shoots (stolons) (Fabaceae) allow endemics to spread over large distances and conquer new territories. Budding reproduction and seed sails allow plants to spread in radical climatic conditions and allow endemics to spread to new territories. The adaptive traits acquired by subnival plant species (e.g. P. digitata) give them advantages in radical climatic conditions. The leafy leaves of the plant are intended to preserve the limited humidity in the area. The dense umbrella-shaped leaves protect the root system from high temperatures resulting from the influence of high radiation here. The relatively long and developed root system helps to take advantage of the moisture in the deep layers of rocks.

Based on the obtained data, 5 Azerbaijani endemics were identified in the studied area based on the comparison of the local data obtained so far in the forest, alpine-subalpine and subnival landscapes within the Azerbaijani borders of the Greater Caucasus with the data of neighboring countries and international flora platforms (Table 11.).

7.3. Factors affecting the flora endemism of the territory.

Relief, lithology or geological structure, microclimate, groundwater and surface water, soil, flora and fauna, eco-morphological characteristics of plants are the main factors affecting endemism. Endemic and pioneer species are mostly species belonging to the families Asteraceae (25/15 species), Caryophyllaceae (13/12 species), Brassicaceae (8/6 species), Lamiaceae (5/5 species), Apiaceae (5/5 species), Boraginaceae (3/2 species), Poaceae (15/5 species), Ranunculaceae (6/4 species), Fabaceae (2/1 species) and Rocaceae (6/2 species) (Figure 10). These species are distinguished by their very small and sail-shaped seeds, hairy and waxy leaves, long, densely branched root system, reproduction by shoots, numerous small flowers and petrophyticity.

Figure 10. Pioneer plant speaces cover of the upper subnivale belt: a–*Archanthemis marschalliana* subsp. *sosnovskyana* (Grierson) Lo Presti & Oberpr; b– *Cirsium isophyllum* (Petr.) Grossh.; c–*Cynoglossum holosericeum* Steven.; d–*Erigeron uniflorus* L.; e–*Jurinella moschus* (Hablitz) Bobrov; f–*Pseudovesicaria digitata* (C.A.Mey.) Rupr.; j–*Ranunculus arachnoideus* C.A.Mey.; g– *Lathyrus formosus* (Steven) Kenicer.

The emergence, survival and spread of endemics by occupying new territories is based on 3 types of factor groups. 1. Solar radiation, microrelief, radical temperature and mineral composition cause the formation of local mutations. 2. Small seeds, hairy and waxy leaves give advantages to endemics in adapting to harsh climatic conditions. Small seeds (Apiaceae, Caryophyllaceae) penetrate deep into gravel piles and debris, allowing them to be protected from radical temperature gradients and frost, and to use the moisture there. 3. Spread. The rotting wood, insects and vertebrates, their excrement and residual rotting, which are widespread here, play the role of microhumus, pollinators and dispersers. The flora species, including the fauna settled in the area, also play an important role in the formation of endemism. They actively participate in the spread of species, change the chemical composition of rocks, and also regulate population size. The number of animals living in the highest zones is limited

Sail- or parachute-shaped seeds help to spread over large areas in windy environments. When the fruits and seeds in the form of a rattle are ripe, they separate from the plant and spread under the influence of gravity and light winds. The rattle-shaped fruits create a “thermos effect” around the seeds, protecting them from sharp daily temperature fluctuations and creating stable temperature conditions.

The shape of the hard and upright stamens allows insects to cling to the stamens in strong winds and easily collect pollen. The seeds of alpine landscape vegetation acquire resistance to harsh climatic conditions due to dense grass cover and tall stature.

Seeds easily survive hot summers and frosty winters among a dense grass layer. At the upper limits of the alpine and subnival zones, this role is replaced by gravel piles and snow cover.

The air between the gravel piles is a poor conductor of heat, weakening the gradient, ensuring that the temperature in the lower layers between the piles remains constant, allowing the absorption of weak decay products, the nitrite layer by seed germs and the root systems of plants. These are species belonging to the classes of

mammals (Carnivora, Artiodactyla, Rodentia), birds (Passeriformes, Galliformes, Coraciiformes), insects (Arctiidae, Noctuidae, Nymphalidae, Papilionidae, Pieridae), arachnids (Eriophyidae, Tetranychidae, Araneidae, Agelenidae)[37,38].

Trophic relationships between these organisms and their population dynamics are the main biotic factors affecting the dynamics of the plant population of the area. The large number of biotic and abiotic factors requires the application of various model approaches to multicomponent population ecology. Animals living in alpine-subnival landscapes feed on various pollens, grasses, berries, plant seeds, and various insects. Sedges develop on the basis of excrement of small rodents and birds. Sedges are a source of food for birds, especially pronghorns (mountain goats, aurochs) widespread in the area.

Endemic species in the area can also arise as a result of geographical isolation of the population from its ancestor under the influence of climatic factors, allopatrically, and on the basis of genetic drift. We believe that Turanecio taraxacifolius (M.Bieb) Hamzaoglu (Senecio taraxacifolius) and Senecio leucanthemifolius subsp., which are widespread in alpine-subnival landscapes. caucasicus (DC.) Greuter Sofieva (S.sosnovskyi) were thus separated from each other (Figure 11.). *Turanecio taraxacifolius* is found at the upper limits of the alpine zone, at altitudes of 3000-3200 m above sea level. It is a tall, round-leaved perennial plant, 20-50 cm high. Senecio leucanthemifolius subsp. caucasicus (DC.) Greuter is found in the subnival zone, at altitudes of 3500-3800 m above sea level. It is an annual plant, 5-15 cm high, with cleft-slice leaves. The first species blooms in July-August and bears fruit in August-September.

---

[37] Yusifov, E.F. Diversity study of scarab beetles belonging to the subfamily Cetoniinae spread in the natural region of the Greater Caucasus of Azerbaijan / E.F. Yusifov, B.A. Ahmadov, V.S. Narimanova // Journal of Entomology and Zoology Studies, – 2016. №4(5), – p. 1118-1122.

[38] Yusifov, E., Ahmadov, E. Faunal Diversity of Azerbaijan // Biodiversity, Conservation and Sustainability in Asia. Volume 1: Prospects and Challenges in West Asia and Caucasus. Nature Switzerland AG: Springer, – april. – 2021,– p. 501-526.

Figure 11. Allopatric speciation in Bazarduzu-Shahdag area: a - *Senecio leucanthemifolius* subsp. *caucasicus* (DC.) Greuter; b - *Turanecio taraxacifolius* (M.Bieb) Hamzaoglu.

The second species, which has drifted relatively higher, blooms a month earlier, in June-August. The extension of the vegetation period is associated with the harsher climatic conditions at the top. Considering that annual plants usually originate from perennial plants, it turns out that Turanecio taraxacifolius is the older and the parent population of these two species. It was divided and fragmented as it rose relatively higher, and gene exchange with the parent population below was interrupted. In order to protect itself from low temperatures and strong winds, the vegetation period of the Senecio population that settled here was prolonged, its height was sharply reduced, and the populations with thin, slicing and hairy leaves acquired the ability to survive in a radical environment. Thus, as a result of the various selective pressures of the new environment, genetic differences arose in the populations of *Senecio leucanthemifolius* subsp. *caucasicus*.

The possibility of vegetative reproduction through stolons in cryophytic environments is an optimal option in extreme environmental conditions. Their main function is to ensure the separation and distance of the offspring from the mother plant, and to provide the newly formed offspring with nutrients during the first stages of ontogenesis. During vegetative reproduction, stolon stems that are temporarily separated from the mother plant in the upper and lower parts of the soil provide the embryo with food in unfavorable

conditions, protect it, facilitate the occupation of new territories, and create a population. If we generalize the above-mentioned provisions, a mathematical dependence is obtained between endemism and biotic and abiotic factors (Figure 12.)

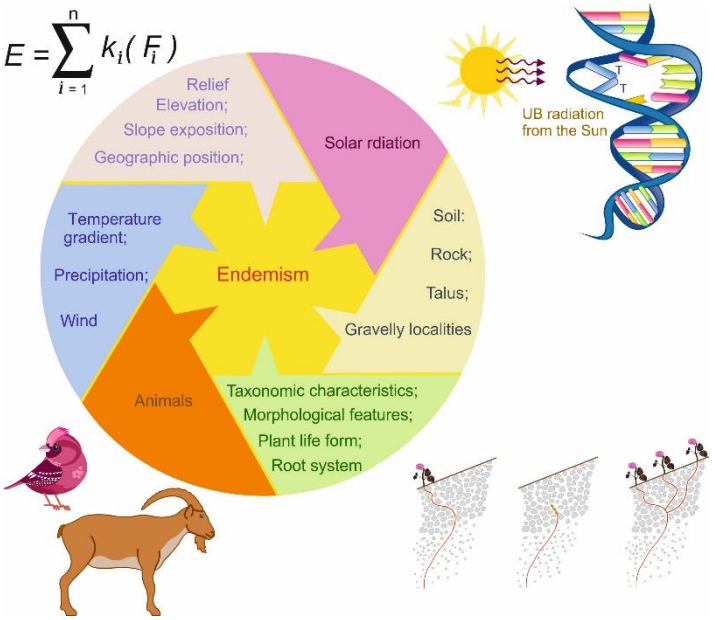

Figure 12. Factors affecting endemism

These factors are grouped into 6 blocks. Each i-factor has a certain coefficient in the endemism process. As a result of climate change, the biomass of alpine areas will increase mainly due to thermophytic plants. In areas with increased average annual precipitation (Zagatala-Balakan), the increase in temperature will lead to an increase in the upper limit of the forest *(Acer heldreichii* subsp. *trautvetteri, Sorbus aucuparia*, *Salix* L., etc.), and in other areas to an increase in tall grasses. If we imagine the shape of the mountains as conical, as mentioned in the previous sections, the rise of cryophyte species of alpine-subnival landscapes to higher altitudes following low temperatures will lead to a decrease in their range.

However, plant populations are subject to multicomponent effects consisting of other macrofactors of the environment, namely biotic potential and environmental resistance (Figure 13). This creates a double effect. As can be seen from the figure, population size is a multiparameter function.

Against the backdrop of climate change, species drift is mainly influenced by 3 ecological factors: 1. The speed of the ability to occupy new territories. This factor affects the distribution of the species across altitudes. 2. The speed of the ability to adapt to new territories. It affects adaptation after arriving in a new territory. 3. The rate of extinction of resident (aboriginal) species Since narrow-range species in subnival landscapes are spread on peaks and lack alternative habitats, they are at high risk. Global warming poses great risks to small-scale species that are distributed in fragments. On southern slopes, the lack of moisture, especially noticeable, poses additional risks to species.

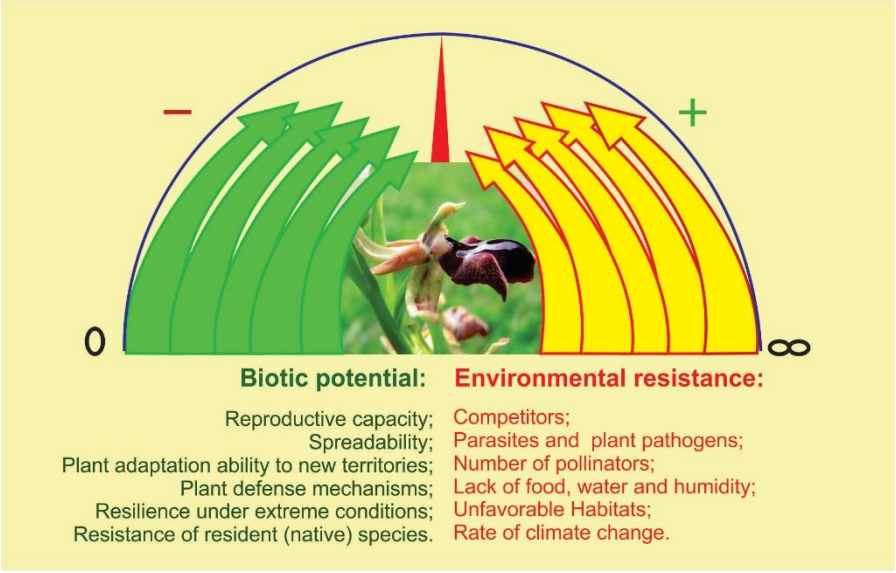

Figure 13. Factors affecting the size of plant populations of alpine-subnival landscapes

CHAPTER VIII
SUBREGIONAL CLASSIFICATION OF RARE SPECIES OF FLORA OF THE TERRITORY

8.1. Rare plant species found in botanical and geographical regions of Alazan-Ayrichay Valley, Western part of Greater Caucasus.

The boundaries of the mentioned botanical-geographical regions coincide with the territories of the Sheki-Zagatala economic-geographical region (Balaken, Zagatala, Sheki, Oguz and Gabala administrative regions). The territory is bordered by the Republic of Dagestan to the north, the Republic of Georgia (Mazim River) to the west, the Girdmanchay Valley to the east, and the Alazan-Ayrichay Depression to the south. The territory is divided into 3 parts according to its natural conditions: the southern slope of the Greater Caucasus; Alazan-Haftaran Valley; the territory of the Middle Kur foothills (Ajinokhur and Turud-Saryca plains, the mountainous part of Sheki). This includes the Gabala, Oguz, Sheki, Gakh, Zagatala and Balaken administrative regions. The rare and endangered plant species of the territory consist of 77 species belonging to 42 families. The rare and endangered plant species of the territory are as follows: *Woodsia alpina* (Bolton) Gray., *Woodsia caucasica* (C.A.Mey.) J.Sm. *(Hymenocystis fragilis* (Trev.) A.Askerov*), Gymnocarpium dryopteris* (L.) Newman, *Adiantum capillus-veneris, Thelypteris palustris, Phegopteris connectilis* (Michx.) Watt, *Juniperus foetidissima, Pinus sylvestris var. hamate (P.kochiana), Taxus baccata* L., *Allium tripedale* Trautv. (*Nectaroscordum tripedale* (Trautv.) Grossh.), *Sternbergia vernalis* (Miller) Gorer & J.H.Harvey (*S.fischeriana* M.Roem.), *Danae racemosa* (L.) Moench, *Diospyros lotus* L., *Crocus speciosus, Iris reticulata* M.Bieb., *Gagea glacialis, Tulipa undulatifolia* var. *undulatifolia (T. eichleri* Regel.*), Punica granatum, Limodorum abortivum, Ophrys apifera, Ophrys sphegodes subsp. mammosa (O.caucasica), O.oestrifera, Orchis mascula* L., *Neotinea ustulata* (L.) R.M.Bateman, Pridgeon & M.W.Chase *(Orchis ustulata), Dactylorhiza romana* subsp. *Georgica* (Klinge) Soó ex Renz & Taubenheim (*Orchis*

flavescens K.Koch), *Coeloglossum viride* Hartm., *Anacamptis collina* (Banks & Sol. Ex Russell) R.M.Bateman, Pridgeon & M.W.Chase *(Orchis collina* Banks & Sol.*), Anacamptis coriophora* (L.) R.M.Bateman, Pridgeon & M.W.Chase *(Orchis coriophora), O.fragrans* Pollini, *Anacamptis morio subsp. picta* (Loisel.) Jacquet & Scappat. *(Orchis picta* Loisel.*), Steveniella satyrioides, Gymnadenia conopsea, Platanthera chlorantha* (Custer) Rchb., *Cephalanthera caucasica* Kraenzl., *Epipactis microphylla* (Ehch.) Sw., *Neottia nidus-avis* (L.) Rich., *A.latifolia***,** *Carum caucasicum* (M.Bieb.) Boiss., *S.graveolens, Hedera pastuchovii* Woronow, *Cladochaeta candidissima, Tanacetum coccineum, T.speciosa, P.digitata, Corylus colurna* L., *C.holosericeum, Omphalodes rupestris* Rupr. ex Boiss., *Buxus sempervivens* (*B colchica), Euonymus velutinus* Fisch.&Mey., *Merendera sobolifera (C.soboliferum), Sempervivum caucasicum, Rhododendron caucasicum, R.luteum, Juglans regia, P.fraxinifolia, Lathyrus formosus, Castanea sativa, Gentiana septemfida* (*G.lagodechiana), Parrotia persica* (D.C.) Mey., *Punica granatum, Phelypaea coccinea, Paeonia daurica* subsp. *mlokosewitschii (P.mlokosewitschii), Veronica telephiifolia, Platanus orientalis* L., *Primula juliae, P.ruprechtii, Aquilegia olympica, Corydalis alpestris, R.arachnoideus, Crataegus pontica* K.Koch, *Lauro-cerasus officinalis* M.Roem. *(Prunus laurocerasus* L.*), Pyracantha coccinea* M.Roem., *Pyrus salicifolia* Pall., *Rubus saxatilis* L., *R.sosnowskyi* (Zahn) Üksip., *R.zakatalensis* Gadzh., *Scrophularia minima* Benth., *Atropa bella-donna* L. *(A.caucasica), Staphylea colchica* Steven, *V.vinifera* L..

8.2. Rare and endangered plant species found in the Botanical and geographical region of the eastern part of the Greater Caucasus.

The boundaries of the mentioned botanical-geographical regions cover the territory of the Upper Shirvan economic-geographical region (Gobustan, Shamakhi, Agsu and Ismayilli administrative regions). The main elements of the Shamakhi-Gobustan lowland are wide plateaus (Gurjuvan, Shamakhi, Maraza plateaus) and low ridges in the west (from Girdmanchay to Maraza). To the north of the Shamakhi plateau is

the Gizmeydan plateau (1000–1400 m), cut by wide and terraced river valleys. In the east are the Gobustan ridges (Gayiblar, Shayiblar, Atyol, Boyuk Siyaki, Bayanata, etc.). Here are located circular plateaus (Kicheli, Donuzluq, Boyukdash, etc.), depressions (Ceyrankechmez, Pirsaat, Garaibad, etc.) and numerous mud volcanoes (Demirchi, Ayrantoken, Nardaran, etc.). The Shamakhi plateau extends from Girdiman in the west to the Gijeki plateau in the east. It is surrounded by the Meysari ridge, the Sundu-Gurbanchi plateau in the north, and the Langebiz ridge in the south. The rare and endangered plant species of the area consist of 49 species belonging to 27 families. The rare and endangered plant species of the area are as follows: *J.foetidissima, T.baccata, Allium tripedale (Nectaroscordum tripedale), Sternbergia vernalis (S.fischeriana), S.colchiciflora* Waldst. & Kit., *Eremurus azerbajdzhanicus, D.racemosa, D.lotus, Iris caucasica* Hoffm., *I.reticulata* M.Bieb., *Tulipa biebersteiniana* Schult.f., *T.undulatifolia var. undulatifolia (T.eichleri* Regel*), Punica granatum, Ophrys sphegodes subsp. mammosa (O.caucasica.), Ophrys oestrifera, Orchis purpurea, C.viride* Hartm., *Anacamptis collina* (*Orchis collina* Banks & Sol.), *O.fragrans* Pollini, *Gymnadenia conopsea* (L.) R.Br., *Platanthera chlorantha, Epipactis microphylla, Triticum boeoticum* L., *Ferula persica* Willd., *Astrantia maxima, C.candidissima, Omphalodes rupestris, Alyssum andinum* Rupr., *Betula pendula* subsp. *pendula (B.microlepis* I.V.Vassil.*), Carpinus schuschaensis* H.J.P. Winkl., *Colchicum szovitsii, Quercus castaneifolia, Punica granatum* L., *Alcea kusjariensis* (Iljin. Ex Grossh.), *Phelypaea coccinea* (M.Bieb) Poir., *Primula auriculata, Cotoneaster saxatilis, Prunus microcarpa* C.A.Mey., *Prunus padus* (*Padus avium), Pyracantha coccinea, Pyrus georgica, P.salicifolia, P.vsevolodii, Rosa komarovii* Sosn., *R.zangezura* P.Jar., *Sorbus subfusca* Boiss., *Populus transcaucasica (P.euphratica), Acer heldreichii* subsp. *trautvetteri, V.vinifera* L..

8.3. Rare plant species found in Guba mountainous massif of the Greater Caucasus, Samur-Davachi plain Botanical-geographical regions.

The boundaries of the mentioned botanical-geographic regions cover the territories of the Guba-Khachmaz economic-geographic

region (Guba, Gusar, Khachmaz and Shabran administrative regions). The territory is surrounded by the Dagestan Autonomous Republic of the Russian Federation from the northwest, the Greater Caucasus Range from the southwest, and the Caspian Sea from the east. It includes the Siyazan, Shabran, Khachmaz, Guba and Gusar regions. The Guba-Khachmaz economic-geographic region is distinguished by its rich flora and fauna, as it is a mountainous zone. The fact that this region is surrounded by Shahdag and Babadag has created favorable conditions for the formation of a mild climate type and rich flora and fauna. The relief is mountainous in the south and west (the northeastern slope of the Greater Caucasus Range, the southeastern part of the Yan Range, etc.), and plains in the north and east (the Gusar inclined plain, the Samur-Devachi lowland). The areas on the sea coast are up to 28 m below ocean level. The maximum height is 4466 m (Bazarduzu Mountain). The rare and endangered plant species of the area consist of 63 species belonging to 41 families. The rare and endangered plant species of the area are as follows: *Woodsia alpina, W.glabella, Woodsia caucasica* C.A.Mey. *(Hymenocystis fragilis* (Trev.) A.Askerov*), J.foetidissima, Pinus kochiana* syn. *P.sylvestris var. hamata, T.baccata, Allium grande* Lipsky, *A.oreophilum* C.A.Mey., *Galanthus alpinus* var. *alpinus (G.caucasicus*), *Sternbergia lutea* (L.) Ker Gawl. ex Spreng., *D.racemosa, D.lotus, Crocus adami* J.Gay., *C.speciosus, I.reticulata* M.Bieb., *Gagea glacialis* M.Bieb., *Tulipa biebersteiniana, T.julia, Cephalanthera longifolia, Himantoglossum formosum, Ophrys sphegodes subsp. mammosa (O.caucasica), O.oestrifera, Orchis mascula* L., *O.purpurea* Huds., *N.ustulata* (L.) R.M.Bateman (*O.ustulata* L.), *Dactylorhiza romana* subsp. *Georgica* (*Orchis flavescens), C.viride* Hartm., *O.collina* Banks & Sol. *(Anacamptis collina), O.coriophora (A.coriophora), O.picta (A.morio* subsp. *picta), O.fragrans, Herminium monorchis* R.Br., *Gymnadenia conopsea* (L.) R.Br., *Platanthera chlorantha, Epipactis microphylla, E.palustris, Neottia nidus-avis, P.auriculata, P.ruprechtii, A.latifolia***,** *Bilacunaria microcarpa* (M.Bieb.) Pimenov et V.N.Tikhom. (*Cachrys microcarpos* M.Bieb.), *C.caucasicum* (M.Bieb.) Boiss., *C.acaule* (M,Bieb,) Boiss., *S.graveolens, H.pastuchovii, Centaurea cheiranthifolia* Willd., *C.emiliae* Huseynova & Garakhani, *C.candidissima, T.coccineum,*

Betula raddeana Trautv., *C.holosericeum, Nonea daghestanica* Kusn., *Omphalodes rupestris, T.involucratum, P.digitata, Celtis caucasica* Willd., *Dianthus ruprechtii* Schischk. ex Grossh., *D.vladimirii, Colchicum szovitsii, Sempervivum caucasicum, Phedimus spurius* (M.Bieb.) Hart. *(Sedum oppositifolium), J.foetidissima, Juglans regia* L., *P.fraxinifolia, A.kubensis* Grossh., *Lathyrus formosus, Quercus pubescens* syn. *Q. pubescens* subsp. *crispata, Gentiana lagodechiana* (syn. *G. septemfida*, *Lomatogonium carinthiacum, Ribes biebersteinii, R.uvacrispa* L. syn. *Grossularia reclinata, Punica granatum, A.kusariensis, P.coccinea, Corydalis alpestris* C.A.Mey., *Veronica telephiifolia* Vahl., *Acantholimon schemachense* Grossh., *Aquilegia olympica* Boiss., *Helleborus orientalis, R.arachnoideus, R.sceleratus, Potentilla agrimonioides, Prunus microcarpa* syn. *Cerasus microcarpa, Prunus padus* L. *(Padus avium), Frangula grandifolia* (Fisch. & C.A.Mey), *Geum rivale* L., *Pyracantha coccinea* M.Roem, *Pyrus georgica* Kuth., *P.salicifolia* Pall., *Rubus saxatilis* L., *Rosa komarovii* Sosn., *R.sosnowskyi* (Zahn) Üksip, *Hedlundia roopiana (Sorbus roopiana), Sorbus subfusca* (Ledeb. Ex Nordum.) Boiss., *Salix kuznetzowii* Laksch. ex Goertz, *Acer heldreichii* subsp. *trautvetteri, Saxifraga exarata* Vill., *S.juniperifolia* Adams., *S.minima* Benth., *A.bella-donna* L., *Vitis vinifera* L..

Ensuring the sustainable development of biological diversity does not end only with environmental awareness, its strict protection and measures to mitigate negative impacts. The issues of meeting people's well-being, recreational needs, industrial development and other socio-economic needs are also very important. This leads to an increase in carbon production and climate change. In this regard, it is very important to assess the carbon cycle in various landscapes in the Greater Caucasus landscapes, and ultimately in Azerbaijan, in order to rationally ensure balanced socio-ecological and economic development. In other words, the carbon dioxide emitted into the atmosphere as a result of the industrial and economic activities of each territory should be set at the

level of the carbon sequestration capabilities of these territorial landscapes[39,40].

CONCLUSIONS

1. For the first time, an analysis and taxonomic analysis of the flora of the Greater Caucasus, distributed within the borders of Azerbaijan, was carried out on forest, alpine-subalpine and subnival landscapes, where a total of 1466 higher plant species were identified. Of these, 885 species are wide-area, and 581 species are endemic species of various ranks. The endemism scale of the area is 66%. 8 of them are South Caucasus, 6 are national endemics of Azerbaijan.

2. For the first time, 672 species belonging to 87 families and 315 genera were identified in the forest landscapes of Azerbaijan. Of these, 156 species are endemic species of various categories, constituting 23% of the landscape flora. 663 species belonging to 66 families and 321 genera were identified in the subalpine-alpine landscapes. Of these, 342 species are endemic species of various categories, constituting 52% of the landscape flora. 131 species belonging to 28 families and 83 genera have been identified in subnival landscapes. Of these, 83 species are endemic species of various categories and constitute 63% of the landscape flora. The endemism of the flora of the area is classified into 6 categories;

3. The degree of stability of taxa in the landscapes of the area (sensitive, stable and developing) has been determined.

---

[39] Двинин, Д.Ю. Моделирование социо-эколого-экономической системы региона при условии перехода к возобновляемым источникам энергии и сохранении углеродного баланса / Д.Ю.Двинин, А.Ю.Даванков, А.Л.Плаксина [и др.] // Актуальные проблемы экологиии природопользования, Сборник трудов XXIII международной научно-практической конференции, – Москва: – 2022, т.1, – с. 96-98.

[40] Dvinin, D. Modeling the balanced development of the region in the transition to renewable energy and maintaining the carbon cycle in land use / D.Dvinin, A.Davankov, A.Plaksina [et all] // VI International Conference on Actual Problems of the Energy Complex and Environmental Protection (APEC-VI-2023), “E3S Web of Conferences 411, 01059”, – 10 august, – 2023, – p. 1-7.

4. The hypsometric dependence of the area's endemism, the ecological index, the ecological autochthonous index have been studied, and an ecological weight scale of the widespread families has been compiled. It has been proven that the Bazarduzu area within the Azerbaijani borders of the Greater Caucasus is the center of speciation in the Caucasus ecoregion.

5. The status of endemic species has been determined, grouped into six categories of endemism. The factors affecting endemism have been studied, and the dependence formula has been given. It has been determined that relief, lithology or geological structure, microclimate, groundwater and surface waters, soil, flora and fauna are the main factors affecting endemism.

6. For the first time, a description and bioecology of 1 new species for the flora of Azerbaijan (*Psephellus paucilobus*), 1 new species for the flora of the Caucasus (*C.fruticosus* Pall.) are given.

7. 5 species found in the area are considered endemic to Azerbaijan. These are *Eremurus azerbajdzhanicus* Kharkev. (Asphodelaceae), *A.kubensis* Grossh. (Fabaceae), *Erodium schemachense* Grossh. (Geraniaceae), *Nepeta longituba* Pojark. (Lamiaceae), *Thymus karjaginii* Grossh. (Lamiaceae).

8. For the first time, the impact of climate change on the flora diversity of forest and high mountain landscapes has been investigated, and the drift of some species towards the height and changes in phytocenosis over the last 50-70 years have been identified.

9. In areas where the average annual amount of precipitation has increased (Zagatala-Balaken), an increase in temperature will lead to an increase in the upper limit of the forest, and in other areas, an increase in tall grasses. As a result, it is predicted that the subalpine plant diversity will be further enriched at the expense of alpine vegetation.

10. For the first time, a Red List of plants distributed within the study areas by botanical-geographical regions has been compiled. Bioecological data on 11 rare and endangered species (*E.azerbajdzhanicus* Kharkev, *Chamaesciadium acaule* (M,Bieb,) Boiss., *C.fruticosus* Pall., *Helleborus orientalis* subsp. *orientalis*, *P.euphratica* Olivier., *Primula algida* Adams. (*P.auriculata* Lam.), *Ribes biebersteinii* Berland. Ex DC., *Saxifraga juniperifolia* Adams.,

Spiranthes sinensis (Pers.) Ames, *Trifolium bordsilovskyic* Grossh., *Lathyrus formosus*) were collected and included in the third edition of the Red Book of Azerbaijan. High-quality photographs of 42 rare and endangered plant, mushroom and animal species included in the third edition of the Red Book of Azerbaijan were taken, and an essay was prepared about 27 species.

11. A list of champion and veteran trees over a hundred years old found in the area, their location and dendrochronological parameters are given.

RECOMMENDATIONS

1. The publication and dissemination of regional red lists of suitable botanical-geographical areas in the Greater Caucasus and their dissemination in communities will have a positive impact on environmental awareness and will provide significant support for the sustainable development of species.

2. Considering the valuable gene pool and ecotourism importance of the old trees of the Greater Caucasus, the compilation of their catalog will better ensure the recognition and protection of these monuments.

3. It is recommended that the species *E.schemachense* Grossh. (Geraniaceae), *N.longituba* Pojark. (Lamiaceae), *Thymus karjaginii* Grossh. (Lamiaceae) be included in the next edition of the Red Book with the status of Azerbaijani endemics of the Greater Caucasus. It is considered appropriate to include the relict species of alpine-subalpine landscapes *Carex flava* L., *Menyanthes trifoliata* L., *Orchis pallens* L., *Papaver orientale* L. in the next edition of the Red Book of Azerbaijan, and to protect Veratrum lobelianum (monotypic, medicinally important ornamental), *Axyris caucasica* (Caucasus endemic), *Serratula caucasica* (Caucasus endemic), *Psephellus paucilobus* (Caucasus endemic), *Cryptogramma crispa* (L.) R.Br. as sensitive species.

4. Since pure subnival species (*Alopecurus dasyanthus, Nepeta supina, Anthemis iberica, Saxifraga mollis, Pseudobetckea caucasica*) are at great risk, it is recommended that they be propagated in botanical gardens and stored in gene banks.

5. It is recommended to adopt a state program for the restoration of tugai forests, fence tugai forests, collect and reintroduce tugai plant seeds in the area, and periodically irrigate the area artificially.

6. The sustainable development of flora in alpine-subnival landscapes largely depends on the activity of insects living here, their pollination ability, and the dynamics of phytopathogenic fungi in the area. In this regard, it is recommended to conduct bio-ecological studies on the mycoflora and entomofauna of the area.

7. Assessment of the carbon cycle is very important in ensuring the sustainable development of biological diversity, balanced socio-ecological and economic development. We consider it important to assess the balance of carbon dioxide emitted as a result of industrial and economic activities of the area and the carbon sequestration capacity of the vegetation and soil cover of this area, and to create carbon landfills.

PUBLISHED SCIENTIFIC PAPERS RELATED TO THE THESIS WORK

1. Yusifov, E.F. Diversity study of scarab beetles belonging to the subfamily Cetoniinae spread in the natural region of the Greater Caucasus of Azerbaijan / E.F. Yusifov, B.A. Ahmadov, V.S. Narimanova // Journal of Entomology and Zoology Studies, – 2016. №4(5), – p. 1118-1122.
2. Каримов, В. Новые для флоры Кавказа виды сосудистых растений из Азербайджана / В. Каримов, Э. Юсифов, Р. Муртазалиев // Ботанический журнал, – С.Пт.: – 2016. №5, – с. 592-594.
3. Юсифов, Э.Ф. Модель динамики численности паукообразных в спектре их межвидовых конкурентных отношений / Э.Ф.Юсифов, А.А.Мамедов, Н.Э.Новрузов [и др.] // Отделение математических наук “Математическое моделирование”, – Российская академия наук, – 2019. №31(4), – с. 131–144.
4. Юсифов, Э.Ф. Таксономическая структура биоразнообразия лесных ландшафтов Азербайджана в условиях климатических изменений // Бюллетень науки и практики. – 2020. №6(7), – с. 75-80.

5. Yusifova, N.A., Mammadov, H.A., Yusifov, E.F. The first record of *Holcogaster fibulata* (Germar, 1831) in Caucasian fauna (Hemiptera: Pentatomidae) // The 5th International Scientific Conference Modern Sciense and Tecnology Innovations. Stockholm, Sweden, – 2020. – p. 272-274.
6. Yusifov, E., Ahmadov, E. Faunal Diversity of Azerbaijan // Biodiversity, Conservation and Sustainability in Asia. Volume 1: Prospects and Challenges in West Asia and Caucasus. Nature Switzerland AG: Springer, – april. – 2021. – p. 501-526.
7. Yusifov, E.F. Phytosenological study of *Zosima absinthifolia* (Vent.) Link. in Azerbaijan // Ninth International Symposium "Steppes of Northern Eurasia". IOP Conf. Series: Earth and Environmental Science. – 2021. v. 817, – p. 75-80.
8. Ibadullayeva, S.J. Yusifov, E.F. Diversity, taxonomic structure of subalpine and alpine vegetation of Caucasus (Azerbaijan and border countries) // Plant & Fungal Research, – 2022. v. 5(1): – p. 2-11.
9. Yusifov, E. Ecological Analyses of Subnival Vegetation of Azerbaijan in the Context of Climate Change // Khazar Journal of Science and Technology, – 2022. v.6 (1), – p. 5-16.
10. Yusifov, E.F. Azərbaycanın subalp-alp landşaftlarının bitki müxtəlifliyinin iqlim dəyişmələri kontekstindən ekoloji analizi // Pedaqoji Universitetin Xəbərləri, Riyaziyyat və təbiət elmləri seriyası, – 2022. 70(2), – s. 79-88.
11. Двинин, Д. Ю. Моделирование социо-эколого-экономической системы региона при условии перехода к возобновляемым источникам энергии и сохранении углеродного баланса / Д.Ю. Двинин, А.Ю. Даванков, А.Л. Плаксина [и др.] // Актуальные проблемы экологиии природопользования, Сборник трудов XXIII международной научно-практической конференции, – Москва: – 2022. т.1, – с. 96-98.
12. Yusifov, E.F., Ibadullayeva, S.J. The common sub-endemic plant species of Azerbaijan and Turkey found in alpine-subalpine and subnival belts // Second bilateral workshop on science between Dokuz Eylül University and Azerbaijan Academy of Sciences, – 18 november, – 2022. – p. 9.

13. Dvinin, D. Modeling the balanced development of the region in the transition to renewable energy and maintaining the carbon cycle in land use/ D.Dvinin, A.Davankov, A.Plaksina [et all] // VI International Conference on Actual Problems of the Energy Complex and Environmental Protection (APEC-VI-2023), "E3S Web of Conferences 411, 01059", – 10 august, – 2023. – p. 1-7.
14. Ibadullayeva, S., Yusifov, E., Mustafayev, A. Rare and endangered species of Shahdag National Park (Azerbaijan) with special status. // Biodiversity Journal. – 2023. 14(3). – p.449-458.
15. Yusifov, E.F., Amrahova, F.F. Dominant Species of the Flora of Alpine Landscapes of the Surrounding Areas of Shahdag Mountain (Eastern part of the Greater Caucasus), their Ecological Analysis and Endemism // Plant & Fungal Research. – 2023. v. 6(2), – p. 41-46.
16. Ibadullayeva, S., Yusifov, E., Sadigova, N. Ecological analysis of the flora diversity of the surrounding areas of the Yenikend reservoir // Plant & Fungal Research. – 2023. v. 6(2), – p. 31-37.
17. Юсифов, Э.Ф. Геоботанический анализ тугайных лесов степной зоны Азербайджана // Степи Северной Евразии: материалы X международного симпозиума, под научной редакцией академика РАН А.А. Чибилёва, – Оренбург: ИС УрО РАН, – 2024. – с. 1531-1538.
18. Ибадуллвева, С., Юсифов, Э., Каримов, В. *Psephellus paucilobus* Boiss. (*Asteraceae* Giseke) - новый вид для флоры Азербайджана // С.-Пт.: Ботанический журнал, – 2024. т. (2), – с. 517-528.
19. Yusifov, E. Biodiversity, biogeography and endemism of the forest and high mountain flora of the Azerbaijan part of Greater Caucasus // Acta Botanica Caucasica, – 2024. v.3, №1, – p. 47-58.

The defence will be held on 5 March 2025 at 11:00 at the meeting of the One-time Dissertation Council BED 1.07/1 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Institute of Microbiology, the Ministry of Science and Education of the Republic of Azerbaijan

Address: Az1004, Baku, A.Abbaszade St. 115

The dissertation is available in the library of the Institute of Microbiology of MSE AR.

Electronic versions of the dissertation and abstract are available on the official website of the Institute of Microbiology of MSE AR (https://www.azmbi.az/index.php/az/).

Abstract was sent to the required addresses on 4 February 2025.

Signed for print: 03.02.2025
Paper format: 60x84 1/16
Volume: 78374
Number of hard copies: 20