

Ecological Analyses of Subnivale Vegetation of Azerbaijan in the Context of Climate Change

Elman Yusifov

Institute of Botany of ANAS, Laboratory of Ethnobotany

Assos/ prof., PhD in Physics

yusifov_e@yahoo.com

Abstract

The study is devoted to the analysis of changes in the structure and distribution of vegetation in the subnivale landscapes of Azerbaijan in the context of climate change. As a result of the conducted research, it was found that the vegetation of the subnivale landscapes of Azerbaijan consists of 136 species belonging to 28 families and 83 genera, and makes up 3% of the country's flora. Among the families, *Asteraceae* (25), *Poaceae* (15), *Caryophyllaceae* (13), *Brassicaceae* (8), *Saxifragaceae* (7), *Ranunculaceae* (6), *Lamiaceae* (5) are the richest and dominant ones. As a result of a comparative analysis of the data obtained with the data from the middle of the last century, it was found that 93 of these species previously lived in alpine-subalpine landscapes and only in the last 70 years have risen to subnivale landscapes. The main reason for this upward shift is thought to be the impact of recent global warming. Out of these, 43 species, belonging to 11 families, were described at altitudes of 3000 - 3800 m at the beginning of the last century. The families that previously existed in the subnivale landscapes are: *Poaceae*, *Apiaceae*, *Asteraceae*, *Brassicaceae*, *Caryophyllaceae*, *Lamiaceae*, *Ranunculaceae*, *Rosaceae*, *Saxifragaceae*, *Scrophulariaceae*, *Valerianaceae* are "aborigene" taxa. The families that have risen to altitudes of 3500 m or more are relatively new ones: *Aspleniaceae*, *Boraginaceae*, *Cyperaceae*, *Juncaceae*, *Crassulaceae*, *Ericaceae*, *Fabaceae*, *Campanulaceae*, *Geraniaceae*, *Gentianaceae*, *Papaveraceae*, *Orobanchaceae*, *Onagraceae*, *Liliaceae*. 85 endemic species (63 %) have been described in the territory.

Keywords: biodiversity, climate change, global warming, flora, subnivale, landscape

Introduction

The biological diversity of subnival landscapes is particularly interesting from their biological, ecological and physiological point of view. These plants live in a relatively harsh climate, with reduced air density. Because their habitats are relatively small, changes in climatic factors are reflected in the size of the populations of these organisms. Subnival landscapes are under extreme pressure in this regard. Over the past 20 years, the melting of glaciers in Azerbaijan has led to a sharp change and warming of the climatic conditions of subnival creatures.

Sufficient research has been conducted on the vegetation and endemism of the upper alpine and subnival landscapes of the Middle and Eastern Caucasus (Abdulaev K.A. et al., 2011; Astamirova M.A et al., 2020; Taisumov M.A. et al. 2017; Murtazaliev R. A., 2012; Nakhutsrishvili G.Sh., 1998). However, there is no systematic research data on the vegetation of the subnival zone of the Southern part of the East Caucasus. Recent global warming and the rapid melting of glaciers have been leading to a dramatic change in the environmental conditions of vegetation in the area. Glacier inventories from 1960, 1986 and 2014 confirm this evidence. Thus, the total area of glaciers decreased by $28.8 \pm 4.4\%$ between 1960 and 2014 (Levan G. Tielidze and Roger D. Wheate. 2018).

Material and methods

High mountain subnival landscapes in Azerbaijan, mainly in the Greater Caucasus, cover areas from 3,200 to 3,500 m to 4,000 m, depending on the terrain and climatic features of the area. The average temperature of the hottest month is $0 - 5^{\circ}\text{C}$ and below, the temperature of the coldest month is 15°C and below, and the average annual temperature is below 0°C . The average annual rainfall is 900-1200 mm (Geography of the Republic of Azerbaijan, 2015).

As the altitude increases, the density of the atmosphere decreases, leading to an increase in solar radiation. On the other hand, the fact that the long-wave radiation of the Earth's surface is higher than that of insolation, air temperature is sharply reduced here (Isachenko A. G., 1991).

The area is highly endemic. The main reason for this is that the alignment of mountain systems in the region creates a characteristic barrier effect of the terrain. These unique mountain barriers, which block the flow of air, play an important role in landscape creation. This configuration of mountains traps humid air currents, causing precipitation. As a result, a unique air and temperature regime is formed.

This, in turn, creates unique climatic conditions and high endemism. The landscape of the area belongs to the nival and subnival landscapes of high mountains (3000 - 4000 m) with cold, temperate-humid climate (Zernov A.S., 2006) .

The materials and information were collected by the author on the basis of expedition research and scientific literature of 2013-2020 period.

Here, mainly petrophytes: plants of rock substrates (hasmophytes), avalanches and moraine are predominant. The class Polypodiopsida is represented by the family Aspleniaceae . Monocotyledons are represented by the families Poaceae, Cyperaceae and Juncaceae . The class Magnoliopsida is represented by 24 chapters. As a result of the research, it was determined that 128 species belonging to 28 genera and 86 genera are distributed in the subnival landscapes of the flora of Azerbaijan.

Lamium tomentosum, *Nepeta supina*, *Myosotis alpestris*, *Senecio karjaginii* species are found on the avalanche deposits of clayey shales in the valley areas. On rocks, rocky and gravel slopes and on moraines are found the following species *Alopecurus dasyanthus*, *Silene humilis*, *S.lacera* and *Pseudovesicaria digitata*. *Taraxacum porphyranthum*, *Tripleurospermum caucasicum*, *Senecio karjaginii*, *Erigeron alpinus*, *Scrophularia minima* are widespread in Morens and wetlands .

Table 1 - shows the taxonomic structure and comparative indicators of flora diversity of subnival landscapes of Azerbaijan. Table 2 - presents the dominant genus of flora diversity of subnival landscapes of Azerbaijan, a comparative analysis of their characteristics.

For example, *Asteraceae* (25 species), *Poaceae* (15 species) and *Caryophyllaceae* (13 species) are the most diverse species in the landscape. This is 38% of the total number of species found in the subnival landscape. The chapters listed in Table 3 are the ones to be safe and under development because of their rich diversity. The taxonomic structure of dominant species is given in Table 4. Out of 83 plant species found in the area, 40 are represented by 3 or more species, which makes 48% of the species diversity in the belt. As can be seen from the table, the richest genus is *Saxifragaceae*, which is represented by 7 species.

However, 4 sensitive genus represented by 1 species have been identified in the area. These are *Geraniaceae* (*Geranium gymnocaulon*), *Liliaceae* (*Gagea sulfurea*), *Onagraceae* (*Epilobium anagallidifolium*), *Violaceae* (*Viola minuta*).

Table 1. Comparative analysis of the taxonomic structure of flora diversity of subnival landscapes of Azerbaijan with the general flora

№	Class	Families, n		%	Genera, n		%	Species, n		%
		Region	Flora		Region	Flora		Region	Flora	
1.	Polypodiopsida	1	6	17	2	24	4	2	55	3.6
2.	Liliopsida	3	25	12	14	213	6.5	21	958	2.2
3.	Magnoliopsida	24	95	25	67	771	8.7	113	3351	3.2
Total:		28	133	21	83	1015	8.2	136	4388	3.0

Table 2. Dominant families of flora diversity of subnival landscapes of Azerbaijan and their taxonomic structure

№	Families	Genera, n		Species, n		On landscape and genus %-with	
		Subnival	Flora	Subnival	Flora	On the landscape	By genus
Liliopsida							
1.	<i>Poaceae</i>	11	113	5	469	1.7	
Magnoliopsida							
2.	<i>Asteraceae</i>	14	121	25	572	6.8	
3.	<i>Caryophyllaceae</i>	5	34	3	191	8.6	
4.	<i>Brassicaceae</i>	5	82	8	245	5.5	
5.	<i>Saxifragaceae</i>	1	1	7	14	5.5	
6.	<i>Rosaceae</i>	3	33	6	216	4.7	
7.	<i>Ranunculaceae</i>	4	23	6	101	4.7	
8.	<i>Lamiaceae</i>	5	37	5	219	3.9	
9.	<i>Apiaceae</i>	5	70	5	182	3.9	
10.	<i>Scrophulariaceae</i>	2	2	5	58	3.9	

Table 3. Emerging species of flora diversity of subnival landscapes

№	Genera	The families to which it belongs	Number of species		
			In the belt	Florada	%-with
Liliopsida class: 3 genera; 21 species					
1.	<i>Alopecurus</i>	<i>Poaceae</i>	3	13	23.0
Magnoliopsida class: 66 genera, 109 species					
2.	<i>Saxifaga</i>	<i>Saxifragaceae</i>	7	14	50.0
3.	<i>Taraxacum</i>	<i>Asteraceae</i>	5	23	21.7
4.	<i>Gentiana</i>	<i>Gentianaceae</i>	3	9	33.3
5.	<i>Draba</i>	<i>Brassicaceae</i>	3	12	25.0
6.	<i>Cerastium</i>	<i>Caryophyllaceae</i>	5	23	22.0
7.	<i>Minuartia</i>	<i>Caryophyllaceae</i>	3	17	17.6
8.	<i>Sedum</i>	<i>Crassulaceae</i>	3	18	16.7
9.	<i>Senecio</i>	<i>Asteraceae</i>	3	22	13.6
10.	<i>Polygonum</i>	<i>Polygonaceae</i>	3	29	10.3
11.	<i>Ranunculus</i>	<i>Ranunculaceae</i>	3	32	9.3
12.	<i>Veronica</i>	<i>Scrophullariaceae</i>	3	42	7.1
13.	<i>Campanula</i>	<i>Campanulaceae</i>	3	48	6.3
Total			43	279	15.0

Of the 136 species of plants found in the area, 51 species are broad-leaved, and 85 species are endemic species of various categories distributed within limits in the Caucasus Ecoregion. Extensive area vegetation, mainly *Poaceae* (10 species), *Asteraceae* (10 species), *Saxifragaceae* (5 species), *Rosaceae* (4 species) chapters.

Endemism of subnival landscapes. As a result of the analysis, 85 endemic species with different habitats within the Caucasus Ecoregion were identified in the subnival landscapes of Azerbaijan. Of these, 8 species (3 genus, 6 genera) belong to the Liliopsida class, and 77 species (22 genera, 53 genera) belong to the Magnoliopsida class. Based on these findings, it has been determined that the originality of plant diversity in the subnival landscapes of Azerbaijan is 2% of the total flora, and 63% of the landscape flora. *Asteraceae* (25; 15), *Caryophyllaceae* (12, 11), *Brassicaceae* (8; 6), *Poaceae* (15; 5), *Apiaceae* (5; 5), *Lamiaceae* (5; 5), *Ranunculaceae* (6; 4), *Scrophullariaceae* (5; 4) chapters These are the dominant genus of endemic plant species found in the subnival landscapes of Azerbaijan (**Figure 2**).



Figure 2. Endemics of subnival landscapes with different statutes: A. North Caucasus and Transcaucasus: *Senecio sosnowskyi*; B. Caucasus, Turkey: *Cirsium tomentosum*; S. Caucasus, Turkey, Iran: *Sedum tenellum* ; D. Wide range: *Jurinea subacaulis*

Table 4. Distribution of dominant families of endemism of subnival landscapes by subregions

Subendem areas	Total number of species	Number of endemic species within families								
		<i>Asteraceae</i>	<i>Poaceae</i>	<i>Caryophyllaceae</i>	<i>Brassicaceae</i>	<i>Saxifragaceae</i>	<i>Rosaceae</i>	<i>Ranunculaceae</i>	<i>Apiaceae</i>	<i>Lamiaceae</i>
Wide range species	51	10	10	1	2	5	4	2	-	-
North Caucasus and South Caucasus	36	8	-	7	2	-	-	2	2	2
North Caucasus, South Caucasus, Turkey	26	5	-	3	3	2	1	-	-	1
North Caucasus, South Caucasus, Iran, Turkey	22	2	4	2	1	-	1	2	3	2

North Caucasus, South Caucasus, Iran	1	-	1	-	-	-	-	-	-	-
Total	136	25	15	13	8	7	6	6	5	5

Table 5. Caucasian endemics of subnival landscapes of Azerbaijan

№	Genus	Species
Magnoliopsida class: 31 species		
1.	<i>Apiaceae</i>	<i>Chaerophyllum humile</i> (<i>Ch.kiapazi</i>), <i>Symphyloloma graveolens</i>
2.	<i>Asteraceae</i>	<i>Aetheopappus caucasicus</i> , <i>Archanthemis sosnovskyana</i> , <i>Kemulariella rosea</i> , <i>Senecio karjagini</i> , <i>S.sosnowskyi</i> , <i>Taraxacum stevenii</i> , <i>T. tenuisectum</i>
3.	<i>Boraginaceae</i>	<i>Trigonocaryum involucratum</i>
4.	<i>Brassicaceae</i>	<i>Eunomia rotundifolia</i> , <i>Pseudovesicaria digitata</i>
5.	<i>Campanulaceae</i>	<i>Campa nula petrophila</i>
6.	<i>Caryophyllaceae</i>	<i>Cerastium multiflorum</i> , <i>C.kasbek</i> , <i>C.undulatifolium</i> , <i>Minuartia inamoena</i> , <i>M. oreina</i> , <i>Silene humilis</i> , <i>S.lacera</i>
7.	<i>Crassulaceae</i>	<i>Sedum stevenianum</i> , <i>Sempervivum caucasicum</i>
8.	<i>Fabaceae</i>	<i>Astragalus brachytropis</i>
9.	<i>Gentianaceae</i>	<i>Gentian angulosa</i>
10.	<i>Lamiaceae</i>	<i>Teucrium nuchense</i> , <i>Ziziphora puschkinii</i>
11.	<i>Ranunculaceae</i>	<i>Delphinium caucasicum</i> , <i>Ranunculus arachnoideus</i>
12.	<i>Scrophullariaceae</i>	<i>Scrophularia ruprechtii</i> , <i>Veronica caucasica</i> , <i>V.minuta</i>
13.	<i>Valerianaceae</i>	<i>Pseudobetckea caucasica</i>
14.	<i>Violaceae</i>	<i>Viola minuta</i>

As noted in previous studies, another reason for the high endemism here is the orographic nature of the area and the effect of the relief on solar radiation here. The combined effect of these two factors and orographic isolation is one of the factors contributing to the unique vegetation, high endemism (Zernov A.S., 2006). The highest endemism is found in the transitional ecotones at an altitude of 3200-3500 m, where the alpine belt with complex mountain systems passes into the subnival zone.

Over the last 100 years, the average annual temperature in Azerbaijan has increased by 0.3-0.8 ° C (Safarov S. G., 2007). As a result of this change, the average annual rainfall decreased by 23% (Mamedov R.M., 2009). Hence, glaciers (Figure 2) in the

country are almost depleted, the level of high mountain lakes (Tufangol, Turfangol, etc.) has sharply decreased (Figure 3).



Picture 2 . Bazarduzu, the largest glacier in the country in the summer of 2003 and 2018



Picture 3. Tufangol and Turfangol mountain lakes

Results and discussions

A comparative analysis of data from the middle of the last century shows that 93 of the species distributed in subnival landscapes had previously been in alpine subalpine landscapes at altitudes of 1,800 to 2,200 m, and had only risen to subnival landscapes in the last 70 years (Aliyar Ibrahimov and Fatmakhanum Nabiyeva., 2013; Flora of Azerbaijan. 1950; Grossheyim A.A. 1936-1952). These are *Aspleniaceae*, *Boraginaceae*, *Cyperaceae*, *Juncaceae*, *Crassulaceae*, *Ericaceae*, *Fabaceae*, *Campanulaceae*, *Gentianaceae*, *Geraniaceae*, *Papaveraceae*, *Orobanchaceae*, *Liliaceae*, *Onagraceae*, *Polygonaceae*, *Primulaceae*, *Violaceae* species belonging to these genus (Table 6).

The remaining 43 species are aboriginal species and were previously distributed at altitudes of 3300-3700 m (Aliyar Ibrahimov and Fatmakhanum Nabiyeva., 2013; Flora of Azerbaijan. 1950; Grossheyim A.A. 1936-1952). These belong to

Aspleniaceae, Boraginaceae, Cyperaceae, Juncaceae, Crassulaceae, Ericaceae, Fabaceae, Campanulaceae, Gentianaceae, Geraniaceae, Papaveraceae, Orobanchaceae, Liliaceae, Onagraceae, Polygonaceae, Primulaceae and Violaceae genus (Table 7).

As found out, some plants have not changed their positions over the last 70-80 years, while others have risen to an average altitude of 300-500 m or more (Table 8). We believe that the phenological and other features of the relief, slopes, vegetation (thermophilic degree, etc.) play a key/crucial role here.

Table 6. Some species previously distributed in alpine-subalpine landscapes, only in the last 70 years have risen to subnival landscapes

№	Families	Species
1.	<i>Aspleniaceae</i>	<i>Athyrium distentifolium, Cystopteris fragilis</i>
2.	<i>Poaceae</i>	<i>Anthoxanthum odoratum, A.alpinum, Bromopsis variegata, Catabrosella variegata, Colpodium versicolor, Deschampsia flexuosa, Festuca montana, F.woronowii, Helictotrichon pubescens, Nardus stricta, Phleum alpinum, Poa alpine</i>
3.	<i>Cyperaceae</i>	<i>Carex tristis, C.micropodioides, Kobresia persica, K.schoenoides</i>
4.	<i>Juncaceae</i>	<i>Luzula spicata, L.stenophylla</i>
5.	<i>Apiaceae</i>	<i>Chamaesciadium acaule</i>
6.	<i>Asteraceae</i>	<i>Aetheopappus caucasicus, Anthemis melanoma, Anthemis sosnovskyana, Centaurea fischeri, Cirsium obvallatum, C. tomentosum, Kemulariella rosea, Leontodon hispidus, Senecio sosnowskyi, Taraxacum stevenii,</i>
7.	<i>Boraginaceae</i>	<i>Cynoglossum holosericeum, Myosotis alpestris, Trigonocaryum involucreatum</i>
8.	<i>Brassicaceae</i>	<i>Didymophysa aucheri</i>
9.	<i>Campanulaceae</i>	<i>Campanula petrophila, C.saxifraga</i>
10.	<i>Caryophyllaceae</i>	<i>Arenaria lychnidea, Cerastium cerastioides, C.multiflorum, C.purpurascens, Gypsophila tenuifolia, Minuartia aizoides, M.caucasica, M.orienta,</i>
11.	<i>Crassulaceae</i>	<i>Sedum involucreatum, S.tenellum, Sempervivum caucasicum</i>
12.	<i>Fabaceae</i>	<i>Astragalus brachytropis, Vavilovia Formosa</i>
13.	<i>Lamiaceae</i>	<i>Thymus nummularis, Ziziphora puschkinii</i>
14.	<i>Orobanchaceae</i>	<i>Pedicularis crassirostri, P.nordmanniana</i>
15.	<i>Papaveraceae</i>	<i>Corydalis alpestris, C.conorhiza</i>
16.	<i>Polygonaceae</i>	<i>Oxyria digyna, Polygonum alpinum, P.carneum</i>
17.	<i>Ranunculaceae</i>	<i>Anemone speciosa,</i>
18.	<i>Rosaceae</i>	<i>Alchemilla caucasica, Potentilla nivea, Sibbaldia parviflora, S.semiglabra</i>

19.	<i>Scrophulariaceae</i>	<i>Veronica minuta</i>
20.	<i>Violaceae</i>	<i>Viola minuta</i>

Table 7. The main species distributed in subnival landscapes in earlier periods

№	Families	Species
1.	<i>Poaceae</i>	<i>Alopecurus dasyanthus, A.glacialis, A. textilis</i>
2.	<i>Apiaceae</i>	<i>Carum caucasicum, Chaerophyllum humile, Symphyoloma graveolens</i>
3.	<i>Asteraceae</i>	<i>Anthemis iberica, Antennaria caucasica, Erigeron alpinus, E.uniflorus, Jurinella subacaulis, Senecio karjagini, S.sosnowskyi, Taraxacum porphyranthum, Tripleurospermum caucasicum</i>
4.	<i>Brassicaceae</i>	<i>Draba hispida, D.siliquosa, Eunomia rotundifolia, Murbeckiella huetii, Pseudovesicaria digitata</i>
5.	<i>Ranunculaceae</i>	<i>Ranunculus arachnoideus, Thalictrum alpinum</i>
6.	<i>Saxifragaceae</i>	<i>Saxifraga flagellaris, S.juniperifolia, S.moschata, S.pseudolaervis, S.sibirica</i>
7.	<i>Valerianaceae</i>	<i>Pseudobetckea caucasica, Valeriana alpestris</i>

Table 8. Cryophilic species found in subnival landscapes of Azerbaijan

№	Families	Species
21.	<i>Apiaceae</i>	<i>Chaerophyllum humile, Symphyoloma graveolens</i>
22.	<i>Asteraceae</i>	<i>Aetheopappus caucasicus, Anthemis iberica, Cirsium tomentosum, Jurinella subacaulis, Senecio karjagini, S.sosnowskyi, S.taraxacifolius, Taraxacum stevenii, T.tenuisectum, Tripleurospermum caucasicum</i>
23.	<i>Boraginaceae</i>	<i>Myosotis alpestris</i>
24.	<i>Brassicaceae</i>	<i>Draba bryoides, D.siliquosa, Eunomia rotundifolia, Pseudovesicaria digitata</i>
25.	<i>Campanulaceae</i>	<i>Campanula petrophila</i>
26.	<i>Caryophyllaceae</i>	<i>Cerastium cerastioides, C.kasbek, C.multiflorum, C.polymorphum, C.undulatifolium, Minuartia aizoides, M.inamoena, M.caucasica, Silene humilis, S.lacera</i>
27.	<i>Crassulaceae</i>	<i>Sedum stevenianum, S.tenellum</i>
28.	<i>Cyperaceae</i>	<i>Carex tristis</i>
29.	<i>Gentianaceae</i>	<i>Gentian angulosa</i>
30.	<i>Juncaceae</i>	<i>Luzula spicata, L. stenophylla (L.pseudosudetica)</i>
31.	<i>Lamiaceae</i>	<i>Lamium tomentosum, Nepeta supina, Thymus nummuralis, Ziziphora puschkinii</i>

32.	<i>Plantaginaceae</i>	<i>Veronica minuta</i>
33.	<i>Poaceae</i>	<i>Agrostis gigantea</i> , <i>Alopecurus arundinaceus</i> , <i>A.glacialis</i> , <i>Catabrosa aquatic</i> , <i>Nardus stricta</i> , <i>Poa annua</i> , <i>Stipa ehrenbergiana</i>
34.	<i>Primulaceae</i>	<i>Androsace lehmanniana</i>
35.	<i>Ranunculaceae</i>	<i>Ranunculus arachnoideus</i>
36.	<i>Rosaceae</i>	<i>Alchemilla caucasica</i> , <i>A.sericea</i> , <i>Dryas caucasica</i> , <i>Potentilla gelida</i> , <i>P. cryptophila</i> , <i>Sibbaldia parviflora</i> , <i>S.semiglabra</i>
37.	<i>Saxifragaceae</i>	<i>Saxifraga exarata</i> , <i>S. flagellaris</i> , <i>S. juniperifolia</i> , <i>S.moschata</i> , <i>S.sibirica (S.mollis)</i> , <i>S.pontica</i>
38.	<i>Scrophulariaceae</i>	<i>Verbascum georgicum</i> , <i>Scrophularia minima</i> , <i>Veronica caucasica</i> , <i>V.gentianoides</i> , <i>V.minuta (V.telephifolia subsp. telephifolia)</i>
39.	<i>Valerianaceae</i>	<i>Pseudobetckea caucasica</i> , <i>Valeriana alpestris</i>
40.	<i>Violaceae</i>	<i>Viola minuta</i>

The group of cryophilic plants include these edificator species *Alchemilla sericea*, *A. caucasica*, *Alopecurus glacialis*, *Anthemis iberica*, *Cirsium tomentosum*, *Nepeta supina*, *Sedum stevenianum*, *Silene humilis*, *Senecio sosnowskyi*.

References

- Abdulaev K.A., Ataev Z.V., Bratkov V.V.** (2011) Modern landscapes of mountainous Dagestan. Makhachkala, DSPU. 116 pp. (Rep. of Dag.) LBC 911.2 (470.67)
- Aliyar Ibrahimov, Fatmakhanum Nabiyeva.** (2013) Alpine vegetation of the Nakhchivan Autonomous Republic. LAP Lambert Academic Publishing. - 148 p.
- Astamirova M.A-M, Taisumov M. A., Umarov M.U. and Magomadova R.S.** (2020) Analysis of the plant cover of the Upper Alpine belt of the northern part of the Central and Eastern Caucasus. IOP Conf. Series: Earth and Environmental Science 579. 012078. doi:10.1088/1755-1315/579/1/012078
- Ataev Z.V.** (2011) Alpine landscapes of the Eastern Caucasus and their current ecological state. Young scientist. Monthly Scientific Journal. No. 12 (35). Volume I. December, p. 130-134.
- Flora of Azerbaijan.** (1950-1960) Publishing house of the Academy of Sciences of Azerbaijan. In 8 volumes. Baku. From AzFan.
- Geography of the Republic of Azerbaijan.** (2015) Regional geography. Volume III. Baku: Europe. 399 p.
- George Sh. Nakhutsrishvili.** (1998) The Vegetation of the Subnival Belt of the Caucasus Mountains. Arctic and Alpine Research, Vol. 30, No.3, pp. 222-226.
- Grossheyim A.A.** (1936-1952) Flora of the Caucasus. In 8 volumes. Baku. From AzFan.

- Isachenko A. G.** (1991) Landscape science and physical-geographical zoning: Textbook .. M.: Vyssh. school., 366 p.: ill. c 80.
- Levan G. Tielidze, Roger D. Wheate.** (2018) The Greater Caucasus Glacier Inventory (Russia, Georgia and Azerbaijan). The Cryosphere, 12, 81–94. <https://tc.copernicus.org/articles/12/81/2018/>
- Mamedov R.M., Safarov S.G., Safarov E.S.** (2009) Modern changes in the atmospheric precipitation regime on the territory of Azerbaijan // Geography and Natural Resources. Novosibirsk. no. 4, p. 170-175. <http://www.izdatgeo.ru/pdf/gipr/2009-4/170.pdf>
- Murtazaliev R. A.** (2012) Analysis of endemic flora of the Eastern Caucasus and features of their distribution. Bulletin of the Dagestan Scientific Center. No. 47. p. 81–85. <http://vestnikdnc.ru/IssSources/47/7.pdf>
- Safarov S. G.** (2007) Changes in the temperature regime on the territory of Azerbaijan // Gidrometeorol. and ecol., No. 4. pp. 37–46.
- Taisumov M.A., Magomadova R.S., Astamirova M.A-M., Israilova S.A., Khasueva B.A., Khanaeva Kh.R.** (2017) Analysis of the endemism of the xerophyte flora of the Russian Caucasus. //South of Russia: Ecology, Development Vol. 12 N 1. P. 199-205.
- Zernov A.S.** (2006) Flora of the Northwestern Caucasus. Abstract of the dissertation for the degree of Doctor of Biological Sciences. Moscow. 32 p. https://static.freereferats.ru/_avtoreferats/01002937516.pdf