Vegetation of the summit of the natural monument "Mount Beshtau" (Stavropol Krai, Russia)

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Abstract. The characteristics of steppe meadows with subalpine elements of the top of the natural monument "Mount Beshtau" are given with a list of measures for their protection. The Mount Beshtau is the highest of the laccolithic mountains of the Caucasian Mineral Waters (the Central Caucasus). The mountain broad-leaved forests, meadow steppes, steppe and steppe meadows with subalpine elements, characterized by a pronounced altitudinal zonation, are the main types of vegetation in the region. Five vegetation formations were identified on the top of the mountain, based on the ecological-phytocenotic approach. Calamagrosteta arundinaceae and Brachypodieta pinnati formations were considered to belong to steppe meadows with subalpine elements. These plant communities require a compliance with nature conservation measures determined by the status of a natural monument, and this may be named as an ultimate condition for their conservation. In this regard, it seems necessary to increase the environmental awareness, as well as to ban totally the access with quad bikes and uncontrolled visiting the top of the mountain.

1. Introduction
The Mount Beshtau (1,401 m) is a natural sanctuary and the highest of the laccolithic mountains of the Caucasian Mineral Waters (the Central Caucasus). The total area is 3,850.33 hectares. The border of the natural sanctuary was defined by the Decree of the Government of the Stavropol Krai [7].

The climate in the region of the Mount Beshtau is moderately continental with microclimatic features due to the altitudinal zonation and the exposure of the slopes.

The average air temperature in January is -4.1°C, in July, 21.7°C. The average annual air temperature is 8.7°C. Annual precipitation is 500 mm with a maximum in June, humidity factor is 0.63 [1].

The mountain belongs to the group of igneous (palaeovolcanic) cameo mountains of the Caucasian Mineral Waters [7] and has the shape of an irregular oval with a diameter of up to 7 km.

Marls, limestones, sandstones, argillaceous shales, and gypsum-bearing clays are parent rocks. The soils of the Mount Beshtau area are presented by typical micellar-carbonate and leached deepmicellar-carbonate chernozems and gray forest soils, which are formed under the conditions of vertical zonation and complex relief [3]. On the slopes of the mountain, the soil cover is severely disturbed by erosion processes.

The main types of vegetation in the region are mountain broad-leaved forests, meadow steppes, steppe and steppe meadows with subalpine elements with a pronounced altitudinal zonation.
T B Vernander [2] described the absence of the trees on the Mount Beshtau summit and noted a crooked forest belt with *Fagus orientalis* Lipsky, *Betula litwinowii* Doluch., *Quercus petraea* L., and *Rhododendron luteum* Sweet, which gives way to subalpine tall-grass meadows with *Calamagrostis arundinacea* (L.) Roth, *Brachypodium pinnatum* (L.) Beauv., and *Anemonastrum fasciculatum* (L.) Holub and a significant share of steppe species at the 950—1,280 m altitude. This author, like most other researchers [6], believed that the reason for the disappearance of woody vegetation at the top of the mountain was due to a combination of unfavorable climatic factors.

A G Dolukhanov et al. [4] considered the groups of tall grass formations to be the most characteristic of the subalpine belt. These authors argued that the meadows might be considered subalpine if they comprised such environment-forming plants as various species of *Agrostis*, a number of associations of the reedgrass meadows of *Calamagrostis arundinacea*, and a number of others. The authors noted that the vertical boundaries of the subalpine belt fluctuated from 1,700 to 2,300 m above sea level on average, depending on climatic conditions in different regions of the Caucasus. Meantime, the vegetation inversions were often indicated, for example, in depressions, as a result of temperature inversion, etc.

### 2. Materials and methods

The geobotanical studies of plant communities at the summit of the Mount Beshtau were carried out in 2018—2019 using the ecological-phytocenotic approach for vegetation classification [9]. Geobotanical descriptions were performed on the sites ranging in size from 25 to 100 m$^2$, the projective cover was estimated as a percentage. In total, thirty geobotanical descriptions were made, the data were then introduced into the "Beshtau" database, developed using the TURBOVEG program [5] and processed in the JUICE program [10]. Latin names of plants are given according to S K Cherepanov [7].

### 3. Results and discussion

Five plant formations were identified; their composition, structure, ecology, and habitats were characterized.

*Calamagrostetalia arundinaceae* and *Brachypodietalia pinnati* formations were considered as the steppe meadows with subalpine elements.

Communities of *Calamagrostetalia arundinaceae* formation (figure 1, table 1) were found on the north-western slope at the mountain summit at the 1230—1261-m altitude and a slope of 10-30°.

![Figure 1. Communities of Calamagrostetalia arundinaceae formation.](image-url)
The floristic richness is 20—50 species of vascular plants, the total projective cover is 95—100%. The grass stand has 3 canopy levels. The first level is 90—130-cm high, it is sparse and formed by

Table 1. Calamagrosteta arundinaceae formation

| Description no. | 1 | 2 | 3 |
|-----------------|---|---|---|
| Date            | July 2, 2019 | July 2, 2019 | Aug 7, 2019 |
| Geographical coordinates | 44.06.072 N, 043.01.293 E | 44.06.053 N, 043.01.272 E | 44.06.453 N, 043.01.132 E |
| Relief          | upper part of the NW exposure slope, 30° | upper part of the NW exposure slope, 30° | upper part of the NW exposure slope, 10° |
| Altitude of the surveyed site, m above sea level | 1,261 | 1,264 | 1,230 |
| Total projective cover, % | 95 | 100 | 95 |
| Area of surveyed site, m² | 100 | 100 | 100 |
| Association (community type) | Calamagrostis arundinacea, Chamaenerion angustifolium, Agrostis tenuis | Calamagrostis arundinacea, Chamaenerion angustifolium, herbs | Calamagrostis arundinacea, Tanacetum vulgare, Chamaenerion angustifolium |

| Grasses | Pc a | AR b | Pc a | AR b | Pc a | AR b |
|---------|------|------|------|------|------|------|
| Brachypodium pinnatum | 5 | cop2 | 5 | cop1 | 5 | cop2 |
| Calamagrostis arundinacea | 20 | cop3 | 30 | cop3 | 20 | cop3 |
| Agrostis tenuis | 10 | cop2 | . | . | 1 | sp |
| Bromopsis biebersteinii | 7 | cop2 | . | . | . | . |
| Bromopsis riparia | . | . | . | . | 5 | cop2 |
| Helictotrichon armeniacum | 5 | cop2 | . | . | . | . |
| Phleum phleoides | 5 | cop2 | . | . | . | . |
| Sedges | Carex humilis | 5 | cop2 | 5 | cop2 | . | . |
| Herbs | Chamaenerion angustifolium | 20 | cop3 | 25 | cop3 | 10 | cop2 |
| Asperula molluginoides | 5 | cop2 | 5 | cop2 | 3 | cop1 |
| Galium verum | 5 | cop2 | 1 | sp | . | . |
| Origanum vulgare | 5 | cop2 | 2 | cop1 | 1 | sp |
| Stachys officinalis | 5 | cop2 | 1 | sp | . | . |
| Trifolium alpestre | 5 | cop2 | 5 | cop2 | . | . |
| Vicia alpestris | 5 | cop2 | 5 | cop2 | . | . |
| Tanacetum vulgare | . | . | . | . | 15 | cop2 |
| Aconitum nassatum | . | . | . | . | 7 | cop2 |
| Cirsiyum obvallatum | . | . | + sol | 7 | cop2 |
| Filipendula vulgaris | 3 | cop1 | 5 | cop2 | . | . |
| Geranium sanguineum | 2 | cop1 | 5 | cop2 | . | . |
| Inula aspera | 2 | cop1 | 1 | . | 5 | cop2 |
| Galega orientalis | . | . | . | . | 5 | cop2 |
| Seseli libanotis | 3 | cop1 | . | . | 1 | sp |
| Rubus saxatilis | 1 | sp | 3 | cop1 | . | . |
| Chaerophyllum aureum | 1 | sp | 1 | sp | 2 | cop1 |
| Anemonastrum fasciculatum | 1 | sp | 2 | cop1 | . | . |
| Cephalaria gigantea | . | . | 1 | sp | 2 | cop1 |
| Shrubs | Rhododendron luteum | 1 | sp | 1 | sp | . | . |
| Rosa pimpinellifolia | 1 | sp | . | . | 1 | sp |

*Projective cover (%)

abundance rank according to Drude
Calamagrostis arundinacea and Chamaenerion angustifolium (L.) Scop. The second level (60—80 cm) is sparse also, formed by Brachypodium pinnatun, Tanacetum vulgare L., Stachys officinalis L., Anemonastrum fasciculata, and Aconitum nasutum Fisch. ex Rchb. The third one is dense (20—40 cm), formed by Agrostis tenuis Sibth., Carex humilis Leyss., Asperula molluginoides (M. Bieb.) Rchb., Trifolium alpestre L., and Vicia alpestre L. Shrubs are presented by Rhododendron luteum and Rosa pimpinellifolia L. Mesophytic and xeromesophytic species dominate in the communities of this formation.

Brachypodieta pinnati formation (figure 2, table 2) had a similar floristic composition and ecology. Communities of this formation grow on the northwestern and eastern slopes of the Mount Beshtau, at the 1306—1362-m altitude and a slope of 30-35°. The floristic richness is 28—36 species of vascular plants, the total projective cover is 100%. The grass stand is also divided into 3 canopy levels. The first level (90—100 cm) is sparse and presented by Calamagrostis arundinacea, Calamagrostis epigeios (L.) Roth, and Chamaenerion angustifolium. The second level (50—80 cm) is sparse as well and formed by Bromopsis gordjaginii (Tzvelev) Galushko, Agrostis tenuis, Doronicum macrophyllum Fisch. ex Hornem., and Anemonastrum fasciculata. The third one (20—40 cm) is dense and formed by Carex humilis, Geranium sanguineum L., Trifolium alpestre, Asyneuma campanuloides (M. Bieb.ex Sims) Bornm., and Vicia alpestre. Species of the families Asteraceae and Apiaceae play a significant role in the composition of the community. Shrubs are presented by Rosa pimpinellifolia.

![Figure 2](image.png)

**Figure 2.** Communities of the Brachypodieta pinnati formation.

4. Conclusion

Therefore, the complex orography of the Caucasus preconditions the variability of climatic regimes and associated disturbances in the sequential series of zonation in the distribution of particular plant formations. The features of the relief of the Mount Beshtau and the climatic factors caused by these features, such as the amount of precipitation, the ratio of heat and moisture, the strength and speed of the wind, apparently determined the distribution of plant communities uncharacteristic for other laccolithic mountains. They also promoted the appearance of vast areas in the belt of mountain broad-leaved forests steppe meadows, which included the associations where Calamagrostis arundinacea acted as the environment-forming plant, and where such subalpine species as Anemonastrum fasciculata, Asyneuma campanuloides, Vicia alpestre, Aconitum nasutum were quite common.
Table 2. Brachypodieta pinnati formation

| Description no. | Date         | Geographical coordinates | Relief | Altitude of the surveyed site, m above sea level | Total projective cover, % | Area of surveyed site, m² |
|-----------------|--------------|--------------------------|--------|-----------------------------------------------|--------------------------|--------------------------|
| 1               | July 2, 2019 | 44.05.940 N 043.01.292 E | upper part of the NW exposure slope, 35° | 1,349                         | 100                      | 100                      |
| 2               | July 2, 2019 | 44.05.905 N 043.01.295 E | upper part of the E exposure slope, 35° | 1,362                         | 100                      | 100                      |
| 3               | Aug 7, 2019  | 44.05.905 N 043.01.285 E | upper part of the NW exposure slope, 30° | 1,360                         | 100                      | 100                      |
| 4               | July 2, 2019 | 44.05.998 N 043.01.283 E | upper part of the NW exposure slope, 20° | 1,306                         | 80                       | 100                      |

| Association (community type) | Brachypodium pinnatum, Calamagrostis arundinacea, Chamaenerion angustifolium | Brachypodium pinnatum, Calamagrostis epigeios, Chamaenerion angustifolium | Brachypodium pinnatum, Bromopsis gordjaginii, Chamaenerion angustifolium |
|-----------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------|------------------------------------------------------------------------|
| Grasses                     | Brachypodium pinnatum                                                       | Calamagrostis arundinacea                                                | Bromopsis gordjaginii                                                  |
|                             | 40 cop3                                                                     | 20 cop3                                                                 | 5 cop2                                                                 |
| Calamagrostis arundinacea    | 40 cop3                                                                     | 10 cop2                                                                 | 5 cop2                                                                 |
| Bromopsis gordjaginii       | 5 cop2                                                                      | .                                                                        | 20 cop3                                                                |
| Calamagrostis epigeios      | .                                                                           | .                                                                        | .                                                                       |
| Trisetum flavescens         | .                                                                           | .                                                                        | .                                                                       |
| Helictotrichon              | .                                                                           | 10 cop2                                                                 | .                                                                       |
| armeniacum                  | .                                                                           | .                                                                        | 5 cop2                                                                  |
| Phleum phleoides            | .                                                                           | .                                                                        | 2 cop1                                                                 |
| Agrostis tenax              | 5 cop2                                                                      | 1 sp                                                                    | .                                                                       |
| Bromopsis biebersteinii     | .                                                                           | .                                                                        | .                                                                       |
| Sedges                      | Carex humilis                                                              | 5 cop2                                                                  | 5 cop2                                                                 |
| Herbs                       | Chamaenerion angustifolium                                                 | 10 cop2                                                                 | 10 cop2                                                                |
| Doronicum macrophyllum      | 5 cop2                                                                      | 10 cop2                                                                 | 10 cop2                                                                |
| Chaerophyllum aureum        | 5 cop2                                                                      | 5 cop2                                                                 | 5 cop2                                                                 |
| Geranium sanguineum         | 5 cop2                                                                      | 3 cop1                                                                  | 5 cop2                                                                 |
| Vicia alpestris             | 3 cop1                                                                      | 5 cop2                                                                  | 5 cop2                                                                 |
| Rubus saxatilis             | 1 sp                                                                        | 5 cop2                                                                  | .                                                                       |
| Trifolium alpestre          | 1 sp                                                                        | 5 cop2                                                                  | .                                                                       |
| Arneina                      | 3 cop1                                                                      | 3 cop1                                                                  | 5 cop2                                                                 |
| Filipendula vulgaris        | .                                                                           | 3 cop1                                                                  | .                                                                       |
| Oreganum vulgare            | 1 sp                                                                        | 1 sp                                                                    | 5 cop2                                                                 |
| Stachys officinalis         | .                                                                           | 1 sp                                                                    | .                                                                       |
| Valeriana officinalis       | 1 sp                                                                        | 3 cop1                                                                  | 2 cop1                                                                 |
| Anemonastrum fasciculatum   | 1 sp                                                                        | 3 cop1                                                                  | 1 sp                                                                    |
| Galium verum                | 2 cop1                                                                      | 2 cop1                                                                  | 2 cop1                                                                 |
| Shrubs                      | Rosa pimpinellifolia                                                       | .                                                                        | .                                                                       |

| a | b |
|---|---|
| Projective cover (%) | abundance rank according to Drude |

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The compliance with nature conservation measures in regard to the status of a natural monument is a critical condition for the conservation of such plant communities. The Mount Beshtau is a popular tourist destination both among the local population and among at local resorts visitors, which entails an increased anthropogenic load on the ecosystems of the natural sanctuary and numerous violations of the protected regime of the territory. In this regard, it seems necessary to increase the environmental awareness, to broaden efforts aimed at preventing the harvesting of plants for medicinal raw materials and collection for bouquets, as well as to ban totally using the quad bikes and uncontrolled visiting of the summit.

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