On plant communities of arid regions of Altai-Sayan mountains

Natalia Makunina*, Mikhail Telyatnikov, and Evgeniy Zibzeev
Central Siberian Botanical Garden, 630090 Novosibirsk, Russia

Abstract. 8 basic types of plant communities of arid regions of Altai-Sayan mountains have been revealed, their floristic classification has been carried out. Short description of the basic types has been given, their altitudinal distribution has been characterized.

1. Introduction

The South-East Altai and the South-West Tuva (Fig. 1) form the northern outpost of Central Asian arid area, while the main part of Altai-Sayan mountains belongs to the boreal zone. The South-East Altai center is the largest Altaian depression – the Chuya depression (1800–2100 m); the steep flanks of mountain ranges encircle the depression. Kuraisky ridge (2800–3800 m) forms its northern border, the spurs of North Chuysky ridge (2500–3000 m) – the western, and Chikhachev ridge (3000–4000 m) – the eastern, Ukok plateau and the Sailugem ridge (2900–3200 m), – the southern. Rivers of the South-East Altai originate in nearby ridges and flow into Chuya river [1]. The South-West Tuva includes Mongun-Taiga mountains (3400-3900 m), the southwestern flank of Tsagan-Shibetu ridge (3300-3500 m) and Kargy depression (1800-2100 m). Shallow mountain rivulets flow into Kargy river.

Three main types of climate appear to correspond to three main geomorphological units: (1) the climate of Chuya and Kargy depressions, (2) the climate of the flanks of the mountain ridges encircling depressions and plateaus. Low winter temperatures are caused by Siberian anticyclone; the cold air flows down from the slopes, fills the intermountain depressions and creates temperature inversions (January temperature in Chuya depression is –32°C). Mountain slopes are noticeably warmer than depressions: the average January temperature is –16°C. The climatic conditions of mountain flat tops are similar to those in a free atmosphere [2]: the average January temperature at altitude of 3000 m is –18°C. In the summer, the Chuya depression is the warmest place in the South-East Altai: the average temperature in July is +14°C, while on the surrounding mountains slopes it is +11°C. At an altitude of 2500 m, the average July temperature goes down to +8°C, and at an altitude of 3000 m – to +4°C. Annual rainfall in depressions varies from 100 to 150 mm. The surrounding mountain slopes receive up to 400 mm of precipitation; annual rainfall at the height of the snow line reaches 600 mm on the Chikhacheva ridge and 800–1000 mm on the South Chuysky ridge [2].

* Corresponding author: natali.makunina@mail.ru

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (http://creativecommons.org/licenses/by/4.0/).
The altitudinal zone series is known to comprise two belts (altitudinal zones): steppe (1800–2400 m) and alpine (2400–2800 m) one. The limits of altitudinal zones correspond to the main relief forms [3].

![Fig. 1. Geographical position of arid regions of Altai-Sayan mountains.](image)

### 2 Results

#### 1.1 Biodiversity

In arid regions of Altai-Sayan mountains we revealed 8 basic types of plant communities: i – shrub tundra, ii – cryophytic forest, iii – alpine meadow, iv – Kobresia tundra, v – tundra-steppe, vi – cryophytic steppe, vii – petrophytic steppe, viii – dry steppe (bunch-grass typical and desert steppe).

We carried out floristic classification of plant communities of all basic types: dataset of 858 geobotanical releves (published information and unpublished materials of the authors) was analyzed. Most of releves belongs to published syntaxa, some new ones were ascertained on the basis of our unpublished data. The biodiversity of arid region vegetation is 25 associations and communities from 5 classes, 6 orders and 8 alliances (Table 1).

| Class | LOISELEURIO-VACCINIEETEA | Eggler 1952 |
|-------|---------------------------|-------------|
| Order | BETULETALIA ROTUNDIFOLIAE | Mirkin et al. ex Chytrý, Pešout et Anenchonov 1993 |
| Alliance | Empetro-Betulion rotundifoliae | Zhitlukhina et Onishchenko ex Chytrý, Pešout et Anenchonov 1993 |
| 1 Ass. | Flavocetrario nivali-Betuletum rotundifoliae | Telyatnikov 2013 |
| 2 Ass. | Hylocomio splendantis-Caricetum sabynensis | Telyatnikov 2013 |
| 3 Ass. | Aulacommio turgidi-Lagotidetum integrifoliae | Telyatnikov 2013 |

| Class | RHYTIDIO RUGOSI-LARICETEA SIBIRICAE | Korotkov et Ermakov 1999 |
|-------|--------------------------------------|--------------------------|
| Order | FESTUCO OVINAE-LARICETALIA SIBIRICAE | Korotkov et Ermakov et al. 2000 |
| Alliance | Pachypleuro alpini-Laricetum sibiricae | Ermakov in Ermakov et al. 2000 |
| 4 Ass. | Swerto obtusae-Laricetum sibiricae | Makunina 2014 |
| (syn. Polemonio coerulei-Laricetum sibiricae) | ass prov. Telyatnikov 2013 |
| 5 Ass. | Kobresio myosuroides-Laricetum sibiricae | Ermakov in Ermakov et al. 2000 |
| 6 Ass. | Artemisio rupestris-Laricetum sibiricae | Makunina 2014 |
To find out the significance of differences of floristic classification syntaxa and their accordance with basic types of plant communities, we carried out a cluster analysis of floristic classification syntaxa. The dendrogram was made in Past [4] using Ward method.

Two main groups were revealed (Figure 2): 1) high mountain communities and cryophytic forest (i – v), 2) steppes (vi – viii). Shrub tundra (i) belongs to class LOISELEURIO-VACCINETEA, cryophytic forest (ii) – to class RHYTIDIO-LARICETEA. Kobresia tundra (iv) and tundra-steppe (v) represent the class CARICI-KOBRESIETEA: the first one – alliance Kobresion myosuroidis, the second one – alliance Potentillo niveae–Caricion pediformis. Alpine meadow (iii), because of the lack of regional higher taxonomic units, was pre-assigned to the class JUNCETALIA TRIFIDI. Kobresia tundra, tundra-steppe and alpine meadow form one common cluster. All steppe communities were ascribed to class CLEISTOGENETEA SQUARROSAE. Dry steppe was included in the order STIPETALIA KRYLOVII, the others – in the order HELICOTRICHETALIA SHELLIANI: petrophytic steppe belongs to alliance Helicotrichion schelliani, cryophytic one – to alliance Stelario petraeae–Festucion tschuensis.
Fig. 2. Dendrogram of syntaxa. Arabic numerals in the dendrogram correspond to those in the prodromus. i – shrub tundra, ii – cryophytic forests, iii – alpine meadows, iv – Kobresia tundra, v – tundra-steppes, vi – cryophytic steppes, vii – petrophytic steppes, viii – bunch-grass steppes.

1.2 Characteristics of basic plant communities

To give short characteristics of basic plant communities we chosen active species, defining community visual appearance. The activity of the species was calculated as the square root of the multiplication of constancy by mean cover [5]. Very active (activity ≥40), active (40 > activity ≥ 20), and moderately active (20 > activity ≥ 10) species form the core of active species (Table 2). Very active species dominate in plant communities, active ones – codominate; moderately active species are constantly present.

Betula rotundifolia, mosses (Aulacomnium turgidum, Hylocomium splendens, Rhytidium rugosum), and lichens (Cladonia arbuscula, C. stellaris, C. amaurocrea) define the appearance of shrub tundra (i). Larix sibirica dominates in tree layer of cryophytic forest (ii); Betula rotundifolia and Lonicera altaica form shrub layer; tolerant to cold species make up the herb layer. Alpine meadow (iii) has no obvious dominants; Pentaphylloides frictosa, a wide range of alpine species, and tolerant to cold meadow-steppe species (Pulsatilla patens) codominate. Kobresia tundra (iv) has two main dominants: Kobresia myosuroides and Dryas oxyodontha. Tundra-steppe (v) and cryophytic (vi) steppe occur only in arid high mountains; they possess the numerous group of cryophytic species, the most part of which are inactive ones. Their distinctive feature is the simultaneous presence of species of different altitudinal zone groups. Alpine (Carex rupestris, Festuca kryloviana), forest-steppe (Carex pediformis), and steppe (Helicotrichon altaicum) species codominate in tundra-steppes (v); cryophytic species Eremogone meyeri and Saussurea schanginiana are moderately active. Steppe (Koeleria cristata, Helicotrichon altaicum) and forest-steppe (Carex pediformis) species make the core of cryophytic steppe (vi), alpine species have no significant role; in numerous group of cryophytic species only Festuca tschujensis is active. In petrophytic steppe (vii) steppe grasses (Agropyron cristatum, Poa botrioides) dominate; numerous petrophytic herbs are
present, but not active. Dry steppe (viii) are composed of only steppe species (Agropyron cristatum, Artemisia frigida, Poa botryoides).

**Table 2.** Active species of basic plants communities in Altai-Sayan arid regions

| Basic vegetation types | i | ii | iii | iv | v | vi | vii | viii |
|------------------------|---|----|-----|----|---|----|-----|------|
| *Aster alpinus*         | x | x | x | x | x | x | x | x |
| *Carex pediformis*     | x | x | x | x | x | x | x | x |
| *Helictotrichon altaicum* | . | x | x | x | x | x | x | x |
| *Poa botryoides + P. attenuata* | x | x | x | x | x | x | x | x |
| *Betula rotundifolia*  | x | x | x | x | x | x | x | x |
| *Bistorta major*       | x | x | x | x | x | x | x | x |
| *Bistorta vivipara*    | x | x | x | x | x | x | x | x |
| *Carex stenocarpa*     | x | x | x | x | x | x | x | x |
| *Cetraria islandica*   | x | x | x | x | x | x | x | x |
| *Cladonia arbuscula*   | x | x | x | x | x | x | x | x |
| *Festuca altaica*      | x | x | x | x | x | x | x | x |
| *Flavocetraria cucullata* | x | x | x | x | x | x | x | x |
| *Hedysarum austrosibiricum* | x | x | x | x | x | x | x | x |
| *Rhytidium rugosum*    | x | x | x | x | x | x | x | x |
| *Spiraea alpina*       | x | x | x | x | x | x | x | x |
| *Aulacomnium tundricola* | x | x | x | x | x | x | x | x |
| *Cryophytic forests*   | x | x | x | x | x | x | x | x |

**Cryophytic forests, alpine meadows and Kobresia tundra**

| Basic vegetation types | i | ii | iii | iv | v | vi | vii | viii |
|------------------------|---|----|-----|----|---|----|-----|------|
| *Bupleurum multiflorum* | x | x | x | x | x | x | x | x |
| *Kobresia myosuroides* | x | x | x | x | x | x | x | x |
| *Pachypleurum alpinum* | x | x | x | x | x | x | x | x |
| *Potentilla nivea*      | x | x | x | x | x | x | x | x |
| *Alpine meadows, Kobresia tundra and tundra-steppes* | x | x | x | x | x | x | x | x |

| Basic vegetation types | i | ii | iii | iv | v | vi | vii | viii |
|------------------------|---|----|-----|----|---|----|-----|------|
| *Dryas oxyodonta*      | x | x | x | x | x | x | x | x |
| *Flavocetraria nivalis* | x | x | x | x | x | x | x | x |
| *Oxytropis alpina*     | x | x | x | x | x | x | x | x |
| *Carex ledebouriana*   | x | x | x | x | x | x | x | x |
| *Claytonia intermedia* | x | x | x | x | x | x | x | x |
| *Crepis chrysantha*    | x | x | x | x | x | x | x | x |
| *Gentiana alpina*      | x | x | x | x | x | x | x | x |
| *Gentiana grandiflora* | x | x | x | x | x | x | x | x |
| *Lagotis integrifolia* | x | x | x | x | x | x | x | x |
| *Papaver pseudocanescens* | x | x | x | x | x | x | x | x |
| *Patrinia sibirica*    | x | x | x | x | x | x | x | x |
| *Pedicularis oederi*   | x | x | x | x | x | x | x | x |
| *Ptilagrostis mongholica* | x | x | x | x | x | x | x | x |
| *Thamnolia vermicularis* | x | x | x | x | x | x | x | x |

**Cryophytic and petrophytic steppes**

| Basic vegetation types | i | ii | iii | iv | v | vi | vii | viii |
|------------------------|---|----|-----|----|---|----|-----|------|
| *Kobresia tundra and tundra-steppe* | x | x | x | x | x | x | x | x |

**Steppes**

| Basic vegetation types | i | ii | iii | iv | v | vi | vii | viii |
|------------------------|---|----|-----|----|---|----|-----|------|
| *Artemisia frigida*    | x | x | x | x | x | x | x | x |
| *Koeleria cristata*    | x | x | x | x | x | x | x | x |
Notes. xxx – very active species, xx – active species, x – moderately active species, “.” – inactive species. Basic types of plant communities: i – shrub tundra, ii – cryophytic forest, iii – alpine meadow, iv – Kobresia tundra, v – tundra-steppe, vi – cryophytic steppe, vii – petrophytic steppe, viii – bunch-grass steppe.

1.3 Vegetation structure

The steppe belt (1800–2400 m) is confined to the Chuya and Kargy depressions and the adjacent flanks of mountain ranges. The lower subbelt (1800–2100 m) occupies the bottoms of depressions. The background plant community is dry steppe (viii). There are two main forms of relief here. The first form occurs on mountain flanks of the Chuya depression. Steep rocky slopes and screes dominate; the background vegetation is petrophytic steppe (vii). The second form of relief predominates in arid regions; the background plant community is cryophytic larch forest (ii) and cryophitic steppe (vi). In the arid conditions of regions under discussion, forests can exist only due to the moisture received in summer during the melting of the ice permafrost. Cryophytic larch forest (ii) covers concave slopes, while cryophytic steppe (vi) occupies convex ones. In the lower part of the alpine belt (2400–2600 m), the slopes of shadow exposures are covered with shrub tundra (i); the sunny slopes – with Kobresia tundra (iv) and tundra-steppe (v). Tundra-steppe is confined to the stony part of the slopes; Kobresia tundra occupies areas with more developed soils. In the vegetation cover of the upper part of alpine belt (2600–2800 m), Kobresia tundra absolutely dominates. Alpine meadows (iii) occur throughout all alpine belt.

3 Conclusion

Thus, 8 basic types of plant communities were revealed in Altai-Sayan arid region vegetation. Shrub tundra was included in class LOISELEURIO-VACCINIETEA, cryophytic forest – in class RHYTIDIO-LARICETEA; alpine meadow was pre-assigned to class JUNCETEA TRIFIDI. Kobresia tundra and tundra-steppe represent class
CARICI-KOBRESIETEA; steppes were ascribed to class CLEISTOGENETEA SQUARROSAR

The authors are grateful to the Russian Foundation for Basic Research for providing financial support to the research (grant № 18-04-00822 A).

References

1. I.S. Novikov, Morphotectonics of the Altai (Publishing House of Siberian Branch of RAS, Novosibirsk, 2004)
2. V.V. Sevastyanov, Climatic resources of Altai mountains and their applications (Publishing House of Tomsk Pedagogical University, Tomsk, 2009)
3. N.I. Makunina, The fourth international scientific conference “Ecology and geography of plants and plant communities” (2012)
4. Ø. Hammer, PAST Paleontological Statistics. Version 2.17. Reference manual (University of Oslo, Oslo, 2012)
5. L.I. Malyshev, Botanical J., 58 (1973)