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Practice of Geobotanical Indication of Forest Growth Conditions in the Steppe and Wooded Steppe Ecotone in Central Mongolia

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ABSTRACT

The forest conditions in the Central Aimag of Mongolia, located in the southern part of the Baikal catchment area, near the southern border of the forest-steppe subzone, were examined within the framework of this study. The field materials collected in the summer 201–2018 at the Zuunmod Model polygon serve as the core of the study. An ecosystem map of the Model polygon with the scale 1:50 000 and the Key plot with the scale 1:5 000 was drawn up using World View-2 satellite imagery data (2016). The proven method of botanical indication of forest growth conditions is as follows: identification of the ecologic and coenotic groups of plant species, calculation of the moisture coefficient based on the ratio of the number of species included in the groups characterizing the extreme conditions of the moisture gradient and distribution of communities in accordance with the values of the gradient in the ecological series. Communities of stages of ecological series serve as indirect indicators of the forest conditions: *Stage I*: ***Ku*** <1, insufficient humifying for tree growth, *Stage II*: ***Ku*** 1–2, average humifying, *Stage III*: ***Ku*** >2, sufficient humifying for tree growth. The stages also correspond to the landscape conditions and the character of the vegetation cover.

Keywords: Baikal catchment basin, ecosystems, belt and zonal groups of plants, environmental conditions, humidity factor.

INTRODUCTION

Studying the conditions which are favourable for the recovery of forest communities in deforested areas is of relevance for any country; however, even more so for Mongolia, where the share of forests including open woodland and floodplain forests along riverbeds is mere 179,700 km^2 or less than 11.5% of the country's total area [Gunin, Saandar, 2019]. Preservation of forests the existence of which is determinant for favourable ecological conditions in the Lake Baikal catchment basin is of paramount importance. The main factors limiting the tree growth there are soil humidification and anthropogenic effects (livestock grazing, tree felling, and wildfires). The assessment of the environmental conditions in the Mongolia part of the Baikal catchment basin was presented in a large number of articles and monographs [Ecosystems…, 1995; Ecosystems..., 2005; Bazha et al., 2018]; however, the role of belt and zonal groups of plants as indicators has not been studied before. This study is based on the results of the 2017–2018 field work.

The study objective was the indication of the forest growth conditions at the southern limit of the wooded steppe subzone in the Central Mongolia and correlation of the retrieved data with the ecosystems mapping results. The key objectives are mapping and ordination of ecosystems by humidification conditions, differentiation of plant communities' species composition by belt-zone plant groups as indicators of environmental conditions; calculation of humidity factor (***Ku***) and its utilization for the assessment of the forest growth conditions in the region.

Main features of natural conditions in the region being the subject of the study. Under the V.P. Chichagov's geomorphological mapping [National..., 1990], the area is a part of the Central Khentei Region, the Khentei Province which is characterized by medium-altitude mountain terrain with absolute altitudes of 1150–2200 m.

The climate there is extreme continental, with long and cold winters – the long-term average annual temperature in January is –20°C in the daytime and –30° C in the nighttime. A permanent 6–12 cm deep snowpack forms on the northern slopes of mountain ridges, where it stays until late March, especially on nival terraces (relict nival cirques). Summers are warm, with variable weather; average daytime temperature is about +22°C, nighttime temperatures are +11 to +14°C. Average annual total precipitation is about 250–300 mm 90% of which falls in July. Effective heat sum (>10° C) is 1500–2000°C [National...1990; Beresneva, 2006].

According to E.M. Lavrenko's phytogeographical mapping [1990], the area is attributed to the Central Asian subregion, the Daur-Mongolian montane wooded steppe province, the Orkhon-Selenga montane wooded steppe sub-province. Rich forb, sedge, sheep fescue and forb-grass meadow steppes are prevailing there. Hillock slopes and intermontane valley bottoms are covered with low-bunchgrass and spear-grass steppes. In the washouts and hollows at mid-parts of northern slope expositions, small patches of shrubbery and thin birch groves combined with meadow-steppe communities were registered [Map..., 1979; Karamysheva, 1990; National..., 1990].

This territory lies within the main livestock farming regions of Mongolia; therefore, the vegetation there is subject to significant pasture loads [Gunin, Saandar, 2019].

The Zuunmod Model Polygon with an area of 17.8 m^2 is situated at the watershed between the Lake Baikal (Tuul River) and the Amur River catchment basins, on the south-western spurs of the Khentei Midlands, 55 km to the west of Ulaanbaatar City in the Central Aimag of Mongolia (Fig. 1).

The terrain is featured by mid-altitude spurs of the south-western prolongation of the Khentei Ridge divided by valleys with intermittent streams.

Mountain spurs are narrow, with some rounded-shape tops and with bedrock outcrops. The difference in absolute elevations is 300 m; the minimal absolute elevation at the polygon's northern limit is 1565 m a.s.l., in the polygon center elevations of 1650–1800 m a.s.l. are prevalent, the maximum absolute elevation is 1865 m a.s.l. The processes of the physical weathering as well as of eluvium accumulation and blown-in slope deposits are underway on the slopes. In the upper inter-ridge valleys on relatively steep northern slopes with quite common rock material outcrops, distinctive terrain terraces are observed – relict nival cirques where springtime snow melting is slower and rainwater is accumulated. Spur slopes gradually grade into flatter sub-slope diluvial plains of inter-ridge valleys. In the valleys' thalwegs, there are shallow beds of intermittent streams.

The southern limit of the wooded steppe subzone runs within the polygon along the northern macro-slope of the water-dividing ridge,.

The Key plot of 40.0 ha is situated in the eastern part of Zuunmod Model polygon, the apical part of the macro-slope of the water-dividing ridge (Fig. 2) being a part of the Lake Baikal catchment basin. In the south-west, the plot is clinging to an 1865 m a.s.l. summit and includes the ecosystems typical for the polygon. The difference in absolute altitudes is 140 m (1720–1860 m).

MATERIAL AND METHODS

The authors used the materials collected in August-September 2017–2018 on Zuunmod Model polygon and the Key plot. Field mapping of the ecosystems within the Model polygon in a scale of 1:50 000 and within the Key plot in a scale of 1:5 000 was performed using spectral data of World View–2 satellite imagery acquired in 2016. In the course of the field and laboratory works, the polygon's ecosystems map was built using MapInfo 11 software; the developed legend (Table 1) shows the basic features of natural conditions. This enabled us to pre-allocate the types of ecosystems suitable for a botanical indication of the forest growth conditions and to select a representative key plot for detailed geobotanical research.

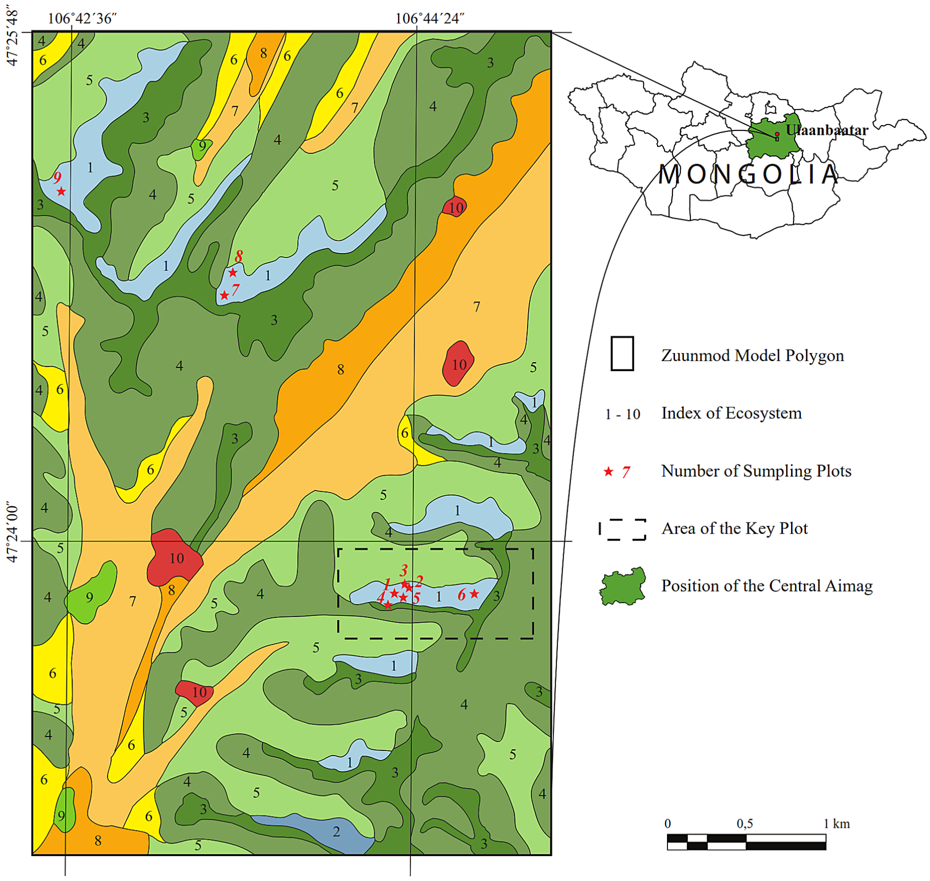


Fig. 1. The geographical location of the studied area

The complete geobotanical descriptions of the plant communities were made for sample plots of 100 m^2 allocated on the hill slopes in northern bearings with different terrain elements. The abundance of tree species was assessed through numbers of individual trees, for other plants the projective cover method was used. Shrubs form two curtains; projective cover of the upper curtain was used as a reference for shrub storey.

Nine geobotanical descriptions were used for the analysis of the forest growth conditions including *Betula fusca* and *Betula microphylla*, six of them (Descriptions 1–6) refer to the Key plot, while other three (Descriptions 7–9) to the plots located at 2–3 km to the north-west, in identical biotopes within the Model polygon limits (Fig. 1). Depending on the features of zonal and belt distribution [Malyshev, Peshkova, 1984], plant species with different strategies of adaptation to humidification conditions form 13 belt-zonal groups. A generalized indicative 'forest' group including *light-coniferous, preboreal* and *dark-coniferous* groups was used as an indicator of the humidification suitable for the tree growth (Table 2). A generalized 'steppe' group including *montane steppe, steppe* and *semi-desert steppe* was used as an indicator of humidification not suitable for trees.

The humidity factor (***Ku***) reflecting the humidification conditions in each community ecotope was calculated. It is equal to the quotient of the number of species present in the belt-zonal groups specific for extreme conditions in terms of the humidity gradient [Miklyaeva and Belyavsky, 2018]:

$$Ku = \frac{l}{c} \tag{1}$$

where: l is the number of plant species within the generalized 'forest' indicative group,
c is the number of plant species in the 'steppe' generalized indicative group.

The ***Ku*** value was calculated for each community based on the number of species in the respective indicative groups. The number of species in the indicative groups is preferred to other indicators such as projective cover, since it is subject to smaller changes throughout the vegetation period.

The plant communities graded from the less humidified to more humidified according to the Ku value, form an ecological series in terms of humidification gradient, which is divided into three stages. Within each stage, the humidity factor has slightly different values that reflect the forest growth conditions: Stage I – unfavourable for tree and shrub growth; Stage II – favourable for shrub growth; Stage III – most favourable for shrub and tree growth. These stages also differ in their plant communities' composition and structure. Similarity of communities' species composition or similarity coefficient (Ko) as established through the Sørensen formula (Greig-Smith, 1964):

$$Ko = \frac{2c}{a+b} \times 100 \quad (2)$$

where: Ko is similarity coefficient,
c is a number of shared species on two plots,
a is a number of species on the first plot,
b is a number of species on the second plot.

RESULTS AND DISCUSSION

Ecosystems of the Model Polygon

A total of nine types of natural ecosystems within the polygon area were identified and mapped (Fig. 1, Table 1).

The plant communities in all types of natural ecosystems are affected by grazing (of horses, sheep and cows), tree and bush felling, wildfires (many plots show signs of fire). The degree of the anthropogenic disturbance in the significant part of ecosystems was estimated as medium to severe. The impact of the following wild herbivores' vital activities is also high: red deer *(Cervus elaphus)*, Tolai hare *(Lepus tolai)*, Daurian pika *(Ochotona daurica),* Brandt's vole *(Lasiopodomys brandti),* tarbagan marmot *(Marmota sibirica)* and long-tailed ground squirrel *(Citellus undulatus)*.

The ecosystems of montane, moderately humid (meadow) steppes are prevalent; their total area is 12.37 km^2 or 69% of the polygon area (Fig. 1, Table 1, indices 3–5). The ecosystems with communities of moderately dry steppes occupy somewhat smaller area – 4.2 m^2 or 23% (indices 6–8).

The area of technogenic ecosystems devoid of natural soil and vegetation cover is insignificant (Fig. 1, index 10).

The relict cirque ecosystems were used for indication of the forest growth conditions. Such are concave piedmonts adjacent to the ecosystems on steep apical northern slopes with patches of shrubbery (yerniks) of *Betula fusca* and with meadow-steppes, the plant composition of which still contains a significant number of forest species (Fig. 1, index 1).

Key Plot ecosystems

An area with the ecosystems typical for the Model polygon was selected as the Key plot. It is located in the polygon's eastern part near the southern limit of yerniks' distribution (Fig. 2).

The Key plot ecosystems form an ecological series in terms of ecotopes' humidification – from the least humidified to the most humidified ones**:** rock buttes covered with crustose lichen (index 1) –> montane meadow-steppe with forbs/petrophyte low-bunchgrasses (2) –> montane meadow-steppe with fringed sagebrush/low-bunchgrasses (3) –> montane meadow-steppe with sedges/forbs/low-bunchgrasses (4) –> meadow-steppe with sedges/sage-brush/grasses (5) –> meadow-steppe with sedges/forbs/grasses (6) –> steppe meadow with grasses/forbs/Kobresiae (7) –> steppe meadow with grasses/rich forbs (8) –> forest-meadow yerniks with sage-brush/sedges/grasses/Kobresiae (9).

The analysis of the possibility of forest regeneration on the Key plot showed that the ecosystems with most humidified ecotopes are suited best for this purpose: steppe meadow (indices 6, 7), shrubby ecosystems of relict cirques (9) as well as meadow-steppe on the northern slopes (4).

A small part of the Key plot (7%) is occupied by the ecosystem of sedges/forbs/low-bunchgrasses (*Festuca lenensis, Agropyron cristatum, Koeleria glauca, Thalictrum minus, Artemisia phaeolepis, Artemisia gmelinii, Carex pediphormis, C. korshinskyi, Kobresia simpliciuscula*) on the montane meadow-steppe with dark lithozem on turfed steep (slope angle of 20–40^o) upper parts of apical northern slopes with distinct solifluction processes and bedrock exposures (index 4).

At the lower periphery of the relict cirques in immediate proximity to meadow-steppe sub-slope plains of inter-ridge valley, ecosystems of steppe meadows with sedges/forbs/grasses (*Agrostis trinii, Poa attenuata subsp. botryoides*) are abundant, with *Dasiphora parvifolia* present on dark-humus lihtozem (index 6; 9% of the area). Higher up the terrain, on the flat parts of cirques adjacent to yerniks, the ecosystem of steppe meadows of

Table 1. Types of ecosystems within the Zuunmod Model polygon

1	**Concave cirque-like piedmonts of steep apical northern slopes** (**relict nival cirques**) with dark-humus and coarse-humus soil underneath the communities of *Betula fusca + Betula microphylla – Agrostis trinii + Bromopsis inermis + Poa nemoralis + Carex lanceolata + Kobresia simpliciuscula*) combined with meadow-steppe communities of *Agrostis trinii – Dasiphora parvifolia,* and *Agrostis trinii + Poa attenuata subsp. botryoides)* and montane meadow-steppe communities of *Carex pediphormis + Kobresia sympliciuscula + K. myosuroides + Festuca lenensis + Agrostis trinii + Thalictrum minus + Aster alpinus + Artemisia phaeolepis + A. gmelinii + Phlomoides tuberosa* on the northern slopes around the cirques on dark-humus lithozem with groups of rock buttes (area of 0.95 km^2)
2	**Flat bases** of **relict nival cirques** with dark-humus and coarse-humus soil underneath low shrub thickets of *Dasiphora parvifolia + Betula fusca,* combined with adjacent steep stone-strewn northern slopes with montane meadow-steppe communities of *Carex pediphormis + Kobresia sympliciuscula + K. myosuroides + Festuca lenensis + Agrostis trinii + Thalictrum minus + Aster alpinus + Artemisia phaeolepis* (area of 0.09 km^2)
3	**Stony (with bedrock exposed) mid-altitude apical surfaces** with lithozem underneath thin montane meadow steppes of *Potentilla sericea + Chamaerhodos altaica + Arenaria capillaris +Festuca lenensis + Poa attenuata subsp. botryoides+ Agropyron cristatum)* combined with *Artemisia dracunculus + Gallium verum + Phlomoides tuberosa + Koeleria glauca + Agrostis mongolica + Poa attenuata subsp. botryoides* in microdepressions with light-humus lithozem (area of 1.78 km^2)
4	**Flattened gravelly apical surfaces and convex well-insolated slopes** with light-humus lithozem underneath montane meadow steppes of *Artemisia frigida + Festuca lenensis + Agropyron cristatum + Poa attenuata subsp. botryoides + Koeleria glauca,* locally degraded *Veronica incana + Dontostemon integrifolia + Potentilla acaulis + Artemisia frigida+ Heteropappus altaicus,* combined with meadow-steppe *of Bromopsis inermis + Agrostis mongolica + Phlomoides tuberosa + Achillea asiatica + Artemisia dracunculus + Rheum undulatum + Aconitum glandulosum* on dark-humus stratozem on concave piedmonts of ridges and in hollows (area of 6.18 km^2)
5	**Well-turfed flat-slope plains in inter-ridge valleys** with dark-humus lithozem underneath meadow steppes of *Carex pediphormis + C. duriuscula + Kobresia simpliciuscula + Poa attenuata subsp. botryoides + Festuca lenensis + Agrostis trinii + Leymus chinensis + Artemisia phaeolepis* (area of 4.49 km^2)
6	**Gravelly flat diluvial plains of broad intermontane valleys** with light-humus soil underneath moderately dry steppes of *Carex duriuscula + Artemisia frigida + Koeleria glauca + Agropyron cristatum + Stipa krylovii + Festuca lenensis* (area of 0.88 km^2)
7	**Flat bottoms of broad intermontane valleys** with light-humus soil underneath grazing-disturbed, moderately dry steppes of *Leymus chinensis + Artemisia phaeolepis + A. adamsii + A. dracunculus + Heteropappus altaicus + Dontostemon integrifolia + Veronica incana* (area of 2.23 km^2)
8	**Low-inclined bottoms of broad intermontane valleys** with light-humus soil with severely disturbed by grazing and vehicles, moderately dry steppes of *Artemisia adamsii + Carex duriuscula* (area of 0.99 km^2)
9	**Microdepressions along thalwegs in broad flat intermontane valleys** with dark-humus, slightly saline soil and saline meadow-steppe communities of *Hordeum brevisubulatum + Leymus chinensis + Carex inervis + Artemisia phaeolepis + A. dracunculus* (area of 0.12 km^2)
10	**Technogenic ecosystems – areas with almost completely destroyed soil and vegetation cover** resulting from road construction, impact from vehicles, earth excavations and development (area of 0.17 km^2)

* Plant names are according to I.A. Gubanov (1996).
** Belt-zonal groups (BZG): I – preboreal, II – dark coniferous forest, III – light coniferous forest, IV – forest-steppe, V – meadow, VI – montane, VII – hypo-arctic-montane and hypo-arctic, VIII – alpine tundra or arctic-alpine, IX – alpine, X – montane steppe, XI – steppe, XII – desert-steppe, XIII – broad.
*** Communities names are given in Table 2.

grasses/forbs/Kobresiae (*Kobresia simpliciuscula*) formed, with inclusions of sparse *Betula fusca*, *Dasiphora parvifolia, Rosa acicularis* on dark-humus lithozem (index 7; 4.3% of the area).

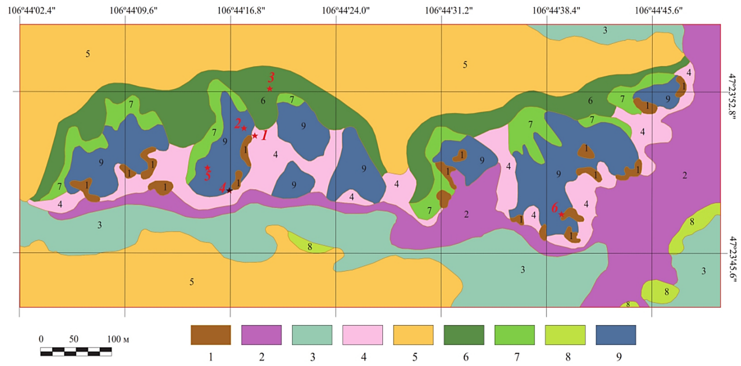
The ecosystem of dense yerniks (index 9: 11.5% of the area) of dwarf birch groves of *Betula fusca* with inclusion of *Betula microphylla* and mesophilous forest-meadow herbage (*Agrostis trinii, Bromopsis inermis, Poa nemoralis, Carex lanceolata, Kobresia simpliciuscula, Artemisia sericea*) is laterally situated on the Key plot in flattened and slightly concave relict cirques with dark-humus coarse-humus soil.

The plant cover of the natural ecosystems within the Key plot is typical for the southern strip of the Khentei forest-steppe belt; it formed under the conditions of intense grazing. The herbage of meadow-steppe and meadow pastures is a good feed for domestic and wild herbivores; it therefore is significantly impacted by grazing. The species composition of these pastures is quite diverse. Thus, the species abundance of meadow-steppes is over 60 species of higher vascular plants.

Belt-zonal characteristics of plant communities' species composition

On the Key plot within the most promising ecosystems such as relict cirques and ecotopes adjacent to them, nine detailed geobotanical descriptions were made for the indication of the forest growth conditions (Table 2). A total of 114 species of higher vascular plants were identified and attributed to 13 belt-zonal groups (BZG) according to Malyshev and Peshkova [1984] (Table 3).

Most species – 92 (81% of the total number of identified species) are members of four belt-zonal groups: montane-steppe (28), forest-steppe



Terrain / Vegetation	Rock buttes	Tops and slopes			Inter-ridge valleys	Humidified piedmonts of steep slopes		
		Rocky apical surfaces	Gravelly convex slopes and apical surfaces	Steep northern slopes	Sub-slope diluvial plains	In northern quadrants: Lower periphery of relic cirques	In northern quadrants: Relic cirques	Other expo-sitions
Crustose lichens	**1**							
Meadow steppes		**2**	**3**	**4**	**5**			
Steppe meadows						**6**	**7**	**8**
Shrubs							**9**	

Fig. 2. The Key plot ecosystems. **1–9** – ecosystems' indices, * ***1–6*** – sampling plots

(22), light coniferous forest (21) and steppe (21 species).

The conditions suitable for the forest communities are indicated by the species of three belt-zonal groups. Their share is 23% of the total number of species identified in the course of the study. Out of those, the light-coniferous group has 21 species such as *Spiraea media*, *Maianthemum bifolium, Sanguisorba officinalis.* The second group – pre-boreal – includes four species: *Betula microphylla*, *B. fusca*, *Vicia megalotropis,* and *Viola sacchalinensis.* The third group – dark-coniferous – is represented by one species – *Poa sibirica*.

The species of arid and dry ecotopes – montane-steppe species (28 plant species accounting for up to 25% of the total number) such as *Amblynotus rupestris*; steppe species (21 species, 18%) – *Cleistogenes squarrossa* and semi-desert steppe species (1 species, 0.9%) – *Thymus gobicus* – are indicators of the unfavourable conditions for the growth of forest communities.

The forest-steppe group encompassing 22 species (19%) such as *Galium boreale*, *Phlomis tuberosa*, *Adenophora stenanthina* indicates fairly arid conditions. This group is in-between the two above groups; therefore, it is not used for the indication of the forest growth conditions.

The ecological series of communities was formed based on the ***Ku*** factor values. On the basis of the close values of the factor, the series was divided into three stages (Tab. 4).

The maximum ***Ko*** was observed in the *Stage III*, the medium ***Ko*** – in the *Stage II*, and the minimum ***Ko*** – in the *Stage I*, which can be explained

Table 2. Plant communities of the Model polygon

No. of description	Community name	Altitude (m)	Geographic coordinates	
			North	East
1	Sage-brush/forbs/wheatgrass/*Carex korshinskyi*	1754	47°23,847	106°44,311
2	Sedge/bentgrass/bromegrass/Kobresia yerniks	1752	47°23,856	106°44,300
3	Sage-brush/sedge/bentgrass/Kobresia yerniks	1745	47°23,887	106°43,325
4	Forbs/Kobresia/sage-brush/*Agrostis trinii*	1772	47°23,808	106°44,281
5	Bentgrass/sedge/Kobresia yerniks	1749	47°23,828	106°44,254
6	Forbs/bromegrass/Kobresia yerniks	1818	47°23,786	106°43,653
7	Sage-brush/forbs/sedge/Kobresia yerniks	1755	47°24,874	106°44,407
8	Light birch forest and forbs/grasses/Kobresia yerniks	1726	47°24,955	106°43,452
9	Forbs/Kobresia yerniks	1750	47°25,262	106°42,565

Table 3. Distribution of plant species by communities and belt-zonal groups

No.	Plant species*	BZG**	Species abundance in communities: - *shrubs, undergrowth and herbs (%)*, - *trees (number of pieces)*								
			Numbers of plant communities***								
			1	4	3	2	7	9	8	5	6
1	*Betula microphylla* Sukacz. (mature trees/regrowth)	I						**0/2**	**4/15**	**1/10**	
2	*Viola sacchalinensis* Boissieu	I	<1	<1	<1	<1	<1	<1	<1	<1	<1
3	*Betula fusca* Pall. Ex Georgi	I	<1		**20**	**68**	**40**	**40**	**25**	**50**	**80**
4	*Vicia megalotropis* Ledeb.	I	<1		<1						
5	*Poa sibirica* Roshev	II				2	1	1	1	<1	**3**
6	*Rubus saxatilis* L.	III							<1		1
7	*Spiraea media* Franz Schmidt	III	<1	<1		<1	<1	<1	1	1	**5**
8	*Maianthemum bifolium* (L.) F.W.Schmidt.	III									<1
9	*Cotoneaster melanocarpus* Fisch. ex Blitt.	III	<1	<1		<1	<1	<1	<1	<1	1
10	*Tanacetum vulgare* L.	III					<1	<1			<1
11	*Euphrasia pectinata* Ten.	III			<1						
12	*Salix kochiana* Trautv.	III	1		<1		<1	<1	<1		
13	*Rosa acicularis* Lindl.	III	<1			**3**	1	1	**10**	**3**	**20**
14	*Festuca ovina* L.	III		**3**			1	1	1	<1	
15	*Sanguisorba officinalis* L.	III	<1	<1	1		**3**	**3**	<1	<1	<1
16	*Moehringia lateriflora* (L.) Fenzl.	III		<1			<1	<1	<1		<1
17	*Draba nemorosa* L.	III	<1	<1	<1	<1	1	1		<1	<1
18	*Vicia unijuga* A. Br.	III				<1	<1	<1	<1		<1
19	*Silene repens* Patr.	III	2						<1		
20	*Elymus sibiricus* (L.)	III	<1		2						
21	*Carex lanceolata* Bootl.	III		**5**	**3**	**10**	**10**	**10**	**9**	1	**4**
22	*Heteropappus hispidus* (Trunb.) Less.	III		<1						<1	
23	*Geranium pratense* L.	III	**3**		<1		**3**	**3**	<1	1	1
24	*Potentilla evestita* Th. Wolf.	III			<1		<1	<1			
25	*Artemisia phaeolepis* Krasch.	III		**7**			**3**	**3**			
26	*Artemisia dracunculus* L.	IV		1		<1				1	
27	*Bromopsis inermis* (Leys.) Holub	IV	**3**		<1	**15**	**3**	**3**	**10**	2	**10**
28	*Galium boreale* L.	IV	1			**3**	<1	<1	1	<1	1
29	*Galium verum* L.	IV		1	<1	**5**	<1	<1			
30	*Vicia cracca* L.	IV	<1				<1	<1	<1	<1	<1
31	*Cerastium arvense* L.	IV	<1				<1	<1			
32	*Carex pediformis* C.A. Mey.	IV									
33	*Myosotis suaveolens* Waldst. et Kit.	IV		<1	<1	<1	2	2	**3**	1	**8**
34	*Hieracium umbellatum* L.	IV					<1	<1			
35	*Phlomoides tuberosa* (L.) Moench.	IV	<1		<1	<1			<1	<1	<1
36	*Trifolium lupenaster* L.	IV		<1	<1		<1	<1		<1	
37	*Scorzonera austriaca* Willd.	IV	<1	<1							
38	*Sedum telephium* (L.)	IV			<1		1	1		1	
39	*Pulsatilla turczaninovii* Kryl. et Serg.	IV									
40	*Artemisia laciniata* Willd.	IV	<1	**7**	**10**		1	1			
41	*Achillea asiatica* Serg.	IV	2		<1	<1	**25**	**25**	<1	**3**	<1
42	*Agrostis trinii* Turcz.	IV	<1	**10**	**10**	**7**				**10**	<1
43	*Festuca lenensis* Drob.	IV	<1	<1							
44	*Adenophora stenanthina* (Ledeb.) Kitag.	IV	**3**	<1							

Table 3. cont.

No.	Plant species*	BZG**	Species abundance in communities: - *shrubs, undergrowth and herbs (%)*, - *trees (number of pieces)*								
			Numbers of plant communities***								
			1	4	3	2	7	9	8	5	6
45	*Taraxacum mongolicum* Hand.-Mazz.	IV		<1					<1		
46	*Schizonepeta multifida* (L.) Briq.	IV	1	<1	<1						
47	*Leymus chinensis* (Trin.) Pilg.	IV		<1							
48	*Festuca rubra* L.	V	<1		1				**10**		
49	*Poa pratensis* L.	V		1						1	
50	*Parnassia palustris* L.	V	<1		<1						
51	*Campanula glomerata* L.	V	**3**		1	<1	<1	<1	**15**	1	
52	*Lomatogonium carinthiacum* (Wulfen) Reichenb.	VI	<1								
53	*Senecio praticola* Schischk. et Serg.	VI	<1	2	**3**					<1	
54	*Aster alpinus* L.	VI	<1	<1							
55	*Saxifraga sibirica* L.	VI	<1								
56	*Rumex acetosa* L.	VII		<1					<1	<1	
57	*Bistorta vivipara* (L.) S.F. Gray.	VII							<1		
58	*Kobresia myosuroides* (Vill.) Fiori	VII		**5**		**20**	**15**	**15**	**15**	**30**	**20**
59	*Kobresia simpliciuscula* (Wahlenb.) Mackenz.	VIII			27						
60	*Chamaenerion angustifolium* (L.) Scop.	III				<1	<1	<1	1		<1
61	*Valeriana altaica* Sumn.	IX					<1	<1	1		
62	*Aconitum glandulosum* Rapaics	IX							<1		1
63	*Artemisia frigida* Willd.	X		<1							
64	*Potentilla pensylvanica* L.	X	2	<1							
65	*Lychnis sibirica* L.	X	2	<1							
66	*Thalictrum foetidum* L.	X	<1	<1			<1	<1	<1		**10**
67	*Veronica incana* L.	X		**7**			<1	<1		<1	
68	*Dianthus versicolor* Fisch. Ex Link.	X	<1	<1	<1		<1	<1			
69	*Potentilla acaulis* L.	X	**3**	<1							
70	*Alyssum obovatum* (C.A. Mey.)	X	<1								
71	*Poa attenuata* subsh. *botrioides* (Trin.) Tzvel.	X		1	<1	<1	1	1	<1	<1	**3**
72	*Stellera chamaejasme* L.	X	<1	1							
73	*Veronica daurica* Stev.	X									<1
74	*Allium bidentatum* Fisch, et Prokh.	X	<1	<1							
75	*Amblynotus rupestris (*Pall. ex Georgi) M.Pop. ex Serg.	X	<1	<1							
76	*Festuca sibirica* Hack.	X	<1								
77	*Oxytropis nitens* Turcz.	X	<1	<1							
78	*Silene jeneseensis* Willd.	X	<1	<1		<1					
79	*Papaver nudicaule* L.	X	<1	<1							
80	*Arenaria capillaris* Poir.	X	<1	<1							
81	*Rheum undulatum* L.	X	<1	<1							
82	*Chamaerhodos altaica* (Laxm.) Bunge.	X									
83	*Iris tigridia* Bunge.	X	<1	<1							
84	*Elymus aegilopoides* (Drob.) Worosch.	X	<1		<1				<1	<1	
85	*Androsace dasyphylla* Bunge	X	<1	<1							
86	*Potentilla sericea* L.	X	1	<1							

Table 3. cont.

No.	Plant species*	BZG**	Species abundance in communities: - *shrubs, undergrowth and herbs (%)*, - *trees (number of pieces)*								
			Numbers of plant communities***								
			1	4	3	2	7	9	8	5	6
87	*Aconopogon (Polygonum) angustifolium* (Pall.) Hara	X	<1	1	<1						<1
88	*Leontopodium campestre* (Ledeb.) Hand-Mazz.	X	<1	1	<1						
89	*Delphinium grandiflorum* L.	X	**3**	<1							
90	*Orostachys malacophylla* (Pall.) Fisch.	X		<1							
91	*Koeleria cristata* (L.) Pers.	XI	<1	**5**	**5**	<1	1	1		<1	
92	*Chenopodium aristatum* L.	XI	<1				<1	<1			
93	*Rumex acetosella* L.	XI	<1								
94	*Androsace septentrionalis* L.	XI		<1							
95	*Erigeron lonchophyllus* Hooc.	XI	**5**	<1							
96	*Cleistogenes squarrossa* Keng.	XI	**3**	<1							
97	*Agropyron cristatum* (L.) Beauv.	XI		<1	1	**15**	**3**	**3**	1		
98	*Artemisia commutata* Bess.	XI	**15**	**3**							
99	*Chamaerhodos erecta* (L.) Bunge	XI		<1							
100	*Carex korshinskyi* Kom.	XI		**5**	**5**		<1	<1	1	**15**	**4**
101	*Gentiana decumbens* L.	XI	<1	<1							
102	*Heteropappus altaicus* (Willd.) Novopokr.	XI	<1	**3**							
103	*Artemisia adamsii* Bess.	XI			**10**					<1	
104	*Astragalus mongolicus* Bunge.	XI		<1	<1						
105	*Linaria acutiliba* Fisch. ex Reichenb.	XI							<1		
106	*Axyris amaranthoides* L.	XI	2			<1					
107	*Dontostemon integrifolius* (L.) C.A.Mey.	XI	<1				<1	<1			
108	*Thalictrum squarrosum* Steph. ex Willd.	XI	<1	<1	<1				<1		
109	*Linaria buriatica* Turcz.	XI	<1	<1							
110	*Medicago ruthenica* (L.) Trautv.	XI	<1	1	<1						
111	*Peucedanum vaginatum* Ledeb.	XI		<1							
112	*Thymus gobicus* Tscherneva	XII	<1								
113	*Chenopodium album* L.	XIII	<1			<1	<1	<1	1	<1	<1
114	Astragalus sp.		<1								
Projective cover of the upper shrub storey			**3%**	**1%**	**20%**	**70%**	**40%**	**40%**	**50%**	**50%**	**80%**
Projective cover of herbage			**65%**	**70%**	**75%**	**80%**	**75%**	**80%**	**75%**	**70%**	**70%**
Species abundance			**67**	**65**	**38**	**26**	**–**	**43**	**39**	**35**	**31**

*** Communities names are given in Table 2.

by their different location upon the terrain. Significantly high ***Ko*** (58–67%) as well as insignificant variation in the factor values registered for the *Stage II* and *III* yernik communities is an evidence of their floristic homogenity. Thus, indication of the forest growth conditions by their species composition showed that the most promising for forest recovery are the conditions typical for *Stage II* and *III* communities. They show the highest values of the humidity factor (***Ku***) from 2 to 3.2. These are the yernik communities (*Nos.* ***2, 7, 5, 9, 8, 6***) occupying the altitudes from 1726 to 1818 m a.s.l. Further communities descriptions are given based on their ***Ku*** factor values.

The community No. ***2*** (*Betula fusca, Kobresia myosuroides, Bromopsis inermis, Agrostis trinii, Carex lanceolata, Galium verum*) occupies the most humidified ecotopes – the concave north-western slope. Its species abundance is the lowest of all studied communities (Table 3). The yernik is tall and dense; however, up to 15% of its shoots show signs of blight. Such shrubs as

Table 4. Ecological series of communities

Serial Nos. of communities*	Values of humidity factor (***Ku***)	Similarity degree (***Ko***), based on the Sørensen coefficient, %
Stage I		
1	0.3	39–73
4	0.3	
3	0.9	
Stage II		
2	2.0	61
7	2.0	
Stage III		
5	2.2	64–71
9	2.2	
8	2.6	
6	3.2	

***** Communities names are given in Table 2.

Rosa acicularis (3% projective cover), *Spiraea media* (<1%) and *Cotoneaster melanocarpus* (<1%) are present. The herbage storey is dense and fairly tall. The major part of the phytomass occupies a relatively thick layer with high projective cover (75%).

The community No. *7 (Betula fusca, Kobresia myosuroides, Carex lanceolata, Geranium pratense, Artemisia phaeolepis*) occupies the middle part of a shallow lateral hollow without any stream bed in the middle part of the north-western slope adjacent to the steep (20–25°) part of the slope. The species abundance is medium (Table 3). The shrub storey is tall, fairly dense. The prevalent species is *Betula fusca*; *Spiraea media, Cotoneaster melanocarpus, Rosa acicularis* and *Salix kochiana* were also registered, however, with small projective cover. Most of the phytomass formed in the small and dense near-ground layer. Numerous inhabited pika burrows were registered; in August, pika stock shoots of *Betula fusca* for winter.

The community No. ***5*** (*Betula fusca, Kobresia myosuroides, Carex korshinskyi, Agrostis trinii*) occupies the lateral hollow. The species abundance is medium (Table 3). One piece of *Betula microphylla* was registered, 3.5 m tall with two trunks 7 cm in diameter, crown diameter is 2×2.5 m. The density and height of yernik and birch undergrowth are medium. Shrubs are represented by *Rosa acicularis* (3%), *Spiraea media* (1%) with blighted shoots and *Cotoneaster melanocarpus* (<1%). The herbage storey is dense, of medium height. Most of the phytomass is concentrated in the thin near-ground layer (5 cm).

The community No. ***9*** (*Betula fusca, Kobresia myosuroides, Achillea asiatica, Geranium pratense*) grows on the flat part (5–7°) of the terrain's nival terrace, on the north-eastern slope adjacent to the steep (45°) upper part of the slope with butte over 7 m in height. The species abundance is medium (Tab. 3). Two dried-out 8-m-long trunks of *Betula microphylla*, broken at the 1-m height were registered*;* their diameters are 17 and 20 cm. The shrub storey's height and density are medium, with *Betula fusca* prevalence and single instances of *Rosa acicularis, Cotoneaster melanocarpus*, *Spiraea media* and *Salix kochiana.* The maximum height of the herbage storey is 60 cm, most of the phytomass is concentrated in the dense near-ground layer (10 cm). Pika burrows were registered there.

The community No. ***8*** (*Betula fusca, B. microphylla, Kobresia myosuroides, Bromopsis inermis, Festuca rubra, Campanula glomerata, Myosotis suaveolens*) occupies the bottom of the valley on the sides of which there are bedrock outcrops in the form of ridges and buttes. The species abundance is medium (Tab. 3). Most likely, this community is a degraded forest outlier. The height and density of shrubs are medium; in addition to *Betula fusca* (50% crown density), *Rosa acicularis* (10%) is prevailing. The herbage storey is dense, of medium height; most of its phytomass is concentrated in the relatively thick layer (15 cm) with large projective cover. Numerous evidences of domestic livestock and pika life activities were registered.

The community No. ***6*** (*Betula fusca, Kobresia myosuroides, Bromopsis inermis, Myosotis suaveolens, Thalictrum foetidum*) occupies the flat-angle (5°) slightly concave plot adjacent to the steep upper part of the slope – the terrain's nival terrace (relict nival cirque). An abundance of the higher vascular plants species is medium (Table 3). Here, the tall and dense shrub storey of *Betula fusca* is present; up to 15% of its crown branches are dry. *Rosa acicularis* and *Spiraea media* are rather common here, *Cotoneaster melanocarpus* is less common. The herbage storey is short and unevenly distributed: very thin under shrubs (up to 10%), up to 70% – on spots between crowns.

Indication of forest growth conditions by plant communities

Meadow-steppe communities of the *Stage I* Nos. ***1*, *4*** and ***3*** (Table 4) indicate insufficient humidification (***Ku*** <1) for forest growth. The share of the *indicative* species is a mere 12–24%. Out of those species, the *Artemisia phaeolepis* and *Carex lanceolata* have the greater coenotic value. The share of the species indicative for humidification insufficient for forest communities amounts to 32–58%. The species of the steppe group such as *Carex korshinskyi* and *Artemisia commutata* have higher coenotic value. The *Stage I* communities have a small number of *Betula fusca* shrubs in suppressed state, they are merely 0.2–0.9 m tall. The share of *Betula fusca* in the total projective cover may reach 20% (in the community No. ***3*** only).

Communities Nos. ***2*** and ***7*** were recognized as indicative for medium humidification (***Ku*** 1–2) (*Stage II* of the ecological series) favourable for *Betula fusca* growth. The share of the generalized *'forest'* group within the communities varies from 38% (in community No. ***2***) to 43% (in community No. *7*). *Carex lanceolata* (*light-coniferous forest* group) and *Betula fusca* (*preboreal* group) have a great coenotic value. The species indicative for insufficient humidification have smaller share: from 19% in the community No. ***2*** to 21% in the community No. *7*. *Agropyron cristatum* (*steppe* group) has a greater coenotic value. Thickets of *Betula fusca* in the communities of this stage are relatively dense (40–68%) and up to 2.5 m tall.

Four communities (Nos. *5, 6, 8* and *9*) indicate humidification favourable for the tree growth (***Ku***>2) within the *Stage III* of the ecological series. The indicative species prevail – their share varies from 37% (community No. *5*), to 52% (community No. *6*). In all communities within the *Stage III* the share of *Betula fusca* (*preboreal* group), *Rosa acicularis* and *Carex lanceolata* (*light coniferous* group) is relatively large. The share of the *steppe* group indicating arid conditions is not high 16% in the community No *6*, 17% – in No *5*, 18% – in No *8*, 21% – in No *9*. Out of these, *Carex korshinskyi* has the highest coenotic value. In the Communities Nos. *5*, *8* and *9* not only mature *Betula microphylla* trees (both live and dead) but also regrowth (with 2 to 5% density) were registered. *Betula microphylla* was not registered in the Community No *6*; however, such species of the *light-coniferous* belt-zonal group as *Maianthemum bifolium* and *Rubus saxatilis* were found there, which is another proof of the possibility of the tree growth.

CONCLUSIONS

Mapping of ecosystems located in the southern part of the Lake Baikal catchment basin, near the southern boundary of the wooded steppe subzone, enabled to identify the ecosystems promising for forest recovery in terms of their environmental conditions. According to the presented data, the meadow-shrubbery complex of the ecosystems of relict nival cirques (flattened piedmont of steep apical northern slopes of middle-altitude mountains) meets those conditions.

On the basis of the the species composition of the existent plant communities, the method applied allows determining whether the forest recovery is appropriate.

The communities within the stages of an ecological series serve as indirect indicators of forest growth conditions: *Stage I* with ***Ku*** <1, *insufficient* humidification for the growth of trees and shrubs; *Stage II* with ***Ku*** value from 1 to 2, *medium* humidification favourable for birch shrub *Betula fusca* growth, *Stage III* with ***Ku*** >2, *sufficient* humidification for birch shrub *Betula fusca* and trees *Betula microphylla* growth. Stages also differ in landscape conditions**:** steep (up to 40°) apical plots of northern slopes with thin soils represent the conditions unsuitable for the growth of shrubs and trees (*Stage I*); *Stage II* – lower flat portions of slopes are suitable for the growth of shrubs; *Stage III* – relict nival cirques on terrain terraces adjacent to the steep parts of slopes where rainwater is accumulated and snowpack stays rather long, represent the conditions favourable both for the growth of shrubs and for trees growth.

Thus, the method of the comprehensive geobotanical descriptions applied in question allows for the quick and substantiated identification of the conditions suitable for forest recovery.

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