Analysis of the landscape structure of the Malyi Khamar-Daban range

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Abstract. The paper considers the landscape study of the Malyi Khamar-Daban Range (western Transbaikalia), located in the basins of the Temnik river (Lake Tagli region) and Torei river (tributary of the Dzhida river). Based on the analysis, a landscape map of a topological level was generated, which presents homogeneous sections (geomers) of natural and natural-anthropogenic geosystems – biogeocenoses. The legend to the landscape map was developed on the basis of the principles of structural and dynamic classification of geosystems, based on the provisions of the doctrine of geosystems, which determine the landscape structure of the territory as the structure of primary and variable states of geosystems. In the legend of the map, taxonomic affiliation, factor-dynamic properties, seriality, and degree of anthropogenic disturbance of geosystems are sequentially displayed. The map displays 23 varieties of biogeocenoses referring to 3 taiga and 1 steppe geom. From factorial-dynamical attributes that determine the conditions of location, geosystems are represented by 6 classes of facies. A distinction needs to be drawn between the primary, pseudo-primary and serial facies. In the study area, 4 degrees of disturbance of geosystems were identified. Conditionally undisturbed geosystems are located mainly in inaccessible territories. The presence of moderate and severe disturbed geosystems is mainly associated with forest fires, local logging, and moderate recreational load and forestry. Areas with the maximum degree of disturbance are confined to agricultural lands and residential territories.

1. Introduction

In recent decades the attention of the world community has been attracted to mountainous areas, which was facilitated by the political, socio-economic and environmental problems of the interaction of mountains and plains, the importance of their landscape-ecological study was realized.

Landscape studies of mountains seem relevant in connection with the slight vulnerability of their nature during rapidly growing development. Natural and anthropogenic disturbances in the unstable equilibrium of mountain nature cause not only irreversible changes in it, but also a sharp response in the form of spontaneous processes that can cause great economic damage.

Khamar-Daban is a mountain range with a length of about 350 km and an area of 30,000 m², located in the South Baikal region between 102° and 107° E along 51° N in the territory of the Irkutsk oblast and Buryatia. In the west, Khamar-Daban ends into the border of Mongolia. The range is separated from the Sayan Mountains by the Tunkinskaya depression. In the north, it breaks off into Lake Baikal. In the east, the continuation of Khamar-Daban is the Ulan-Burgasy Range, from which it
is separated by the Selenga river. In the south the Temnik river divides the range into Khamar-Daban and Malyi (Small) Khamar-Daban. The Dzhidinskaya forest-steppe with the Jida river lay towards the south.

2. Objects, data and methods
The landscapes of the Malyi Khamar-Daban Range located on the territory of western Transbaikalia were selected as the object of study (figure 1). The key plot is located on a wide planate watershed; it also includes parts of the Temnik river basins on the northern macroslope (Lake Tagle region) and Torei (tributary of the Dzhida river) on the southern macroslope of the range. The Malyi Khamar-Daban Range belongs to the Dzhida mountain country. The range has a smooth relief and belongs to the midlands (average height is 1700 m above sea level). On the watershed and in the Lake Tagle region denudation type of relief is developed in the form of plane surfaces of the Paleogene age with flat watersheds covered with a blanket of residual and residual-deluvial deposits. On the southern macroslope, the denudation-erosion type of relief is developed in the form of steep slopes and of medium steepness and different exposures on the rocks of the Paleozoic, Precambrian, as well as Neogene-Quaternary sediments. On relatively wide sections of the Zun-Torei and Barun-Torei river valleys, an accumulative type of relief in the form of alluvial river plains of the Holocene age was established.

![Figure 1. The geographical location of the study area.](image-url)

The climate of the territory is sharply continental, with cold (min -45°C), dry winters and hot (max 38°C) and dry (up to 300 mm/year) summers at the foot of the ridge, and at the top precipitation increases (up to 700 mm/year), and the amplitudes of seasonal temperatures decrease [1].

The soil cover of the study area is diverse due to natural conditions of the region. On the watershed of the Malyi Khamar-Daban taiga gley cryogenic soil of permafrost swampy and taiga peaty soils are widespread. On the shadowy slopes of the range and in the valleys of the Zun-Torei and Barun-Torei rivers, soddy taiga acid soils with podzolized brown soil, taiga gley cryogenic soil, and permafrost-taiga peaty soils are common. In larch cowberry-forbs, soddy taiga soils prevail. At the border of
forest and steppe, soddy taiga saturated and chestnut lithogenic, chernozem low humus soils dominate [2].

The study area is part of the Dzhidinskaya kettle-mountain forest province of larch forests [3]. On the flat watersheds of the study area, the northern slopes of the hills and in the upper reaches of the rivers, taiga spruce-Siberian stone pine larch vegetation is developed. Within the southern slopes of the hills and in the lower parts of the Torei valley, steppes and larch forest-steppes are widespread. On the wide swampy valleys of streams in the area of Lake Taglei meadow-bog vegetation with plots of yerniks are common.

Based on the physico-geographical zoning given to the Landscapes map of the south of Eastern Siberia [4], the study area is at the junction of two provinces of the South Siberian mountain region: 1 – the Khamar-Daban mountain taiga-hollow, 2 – the Selenga-Orkhon hollow-mountain steppe. This fact explains the diversity of the natural conditions of the territory and the manifestation of a wide range of landscapes: mountain-taiga, forest-steppe, steppe, as well as meadow, meadow-bog, yernik-bog in the valleys of rivers and brooks.

Analysis of the landscape structure is performed using GIS technologies based on remote sensing data (Earth remote sensing) (satellite imagery Landsat 8 OLI and SRTM data), field expedition studies, forest inventory materials, integrated landscape, sectoral and topographic maps, as well as literature. The technique of analyzing remote sensing data and generating raster and vector landscape maps is partially described in earlier works [5-7].

Field investigations were carried out with a view to providing data with special attention to landscape characteristics showing the dynamic state of geosystems (factor series, seriality, relief features, rock yield, species and age structure of phytocenosis, succession stages of vegetation restoration and anthropogenic nature transformations).

In constructing and typing landscape sections, we used not only visual interpretation of satellite images, but the MultiSpec program for automatic processing of multi-zone images, with the method of controlled classification with training (the method of spectral-spatial classification ECHO (Extraction and Classification of Homogeneous Objects), taking into account the spatial uniformity of object classes) [8]. At the same time, both cartographic and literary sources, as well as data obtained from field studies describing biogeocenoses, assigned to different geosystems depending on location characteristics were used as an information basis for training samples (key sites).

Raster maps (classification schemes) obtained on the basis of automated analysis of satellite images are used as an informational-spatial basis for creating vector maps.

The legend to the landscape map is developed on the basis of the principles of structural and dynamic classification of geosystems, based on the doctrine of geosystems [4, 6], which determines the landscape structure of the territory as a structure of the primary and variable states of geosystems that reflect their dynamic state.

In generating vector landscape maps and determining the type of location of geosystems, landscape sections are classified taking into account the analysis of the relief morphology: the derivatives of steepness and slope exposure from the SRTM data are compared with the grid of landscape sections [9, 10].

3. Results and discussion

The analysis resulted in a landscape-typological map of a topological level (figure 2), which shows the homogeneous areas of natural and natural-anthropogenic geosystems - biogeocenoses. In the legend of the map, taxonomic affiliation, factor-dynamic properties, seriality, anthropogenic disturbance of geosystems are sequentially displayed.

We identified 3 forest geoms belonging to the mountain taiga groups of the Baikal-Dzhugdzhur and South Siberian geoms, and 1 mountain-steppe geom belonging to the Central Asian steppe landscapes on the study territory. Geosystems are represented by several classes of facies belonging to the following factor-dynamic series: subhydromorphic (along river valleys, streams, intermountain and catchment depressions, in swampy areas), sublithomorphic (on slopes with close bedding of rocks),
subhydrolithomorphic (on flat watersheds and near-watersheds areas, planate and elevated areas), xerolithomorphic (southern slopes with rock outcrops), cryohydrolithomorphic and cryohydromorphic (in planate elevated areas and in swamped areas, with the manifestation of permafrost processes).

Figure 2. A fragment of the landscape map of the Malyi Khamar-Daban Range. Landscapes: see table 1.

Table 1. Legend of the landscape map of the Malyi Khamar-Daban Range.

| Topographic feature (group of facies) | Geosystem | Number on the map |
|--------------------------------------|-----------|-------------------|
| Group of intermountain depressions and valleys of taiga larch forests of optimal development conditions | Yernik with reduced larch and birch subshrub-sedge-sphagnum | 1 |
| Class of cryohydromorphic facies | | |
| Group of serial facies of swamped lake basins of yerniks with areas of swamped meadows on peaty-gley permafrost bog soils | Reduced rare-standing birch-larch forest with yernik subshrub-sedge-sphagnum | 2 |
| Group of serial facies of swamped valleys of streams in yernik with areas of swamped meadows on peaty-gley permafrost bog soils | | |
| Mountain-taiga geom of larch forests of optimal development conditions | Siberian stone pine-larch moss-lichen-subshrub forest | 3 |
| Class of cryohydrolithomorphic facies | | |
### Table 1. Legend of the landscape map of the the Malyi Khamar-Daban Range.

| Topographic feature (group of facies)                                                                 | Geosystem                                                                 | Number on the map |
|-----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|-------------------|
| locations of larch moss-lichensub-shrub forests on permafrost-taiga peaty soils                    | with yernik                                                               | 3a                |
|                                                                                                    | Reduced rare-standing birch-larch forest with yernik                       |                   |
|                                                                                                    | subshrub-sedge-sphagnum                                                   |                   |
|                                                                                                    | **Class of subhydrolithomorphic facies of watersheds and gentle slopes**  |                   |
| Group of primary facies of flat watersheds and near-watersheds areas of larch subshrub-grass forests on podzolized brown and soddy taiga soils | Larch with Siberian stone pine shrub cowberries-grass forest               | 4                 |
|                                                                                                    | Birch-larch forest with Siberian stone pine and shrubs; cowberries-forbs forest |                  |
|                                                                                                    | Larch forbs                                                               | 5                 |
|                                                                                                    | Birch-larch dog-rose forbs forest                                          | 5a                |
|                                                                                                    | Larch-birch forbs open woodland                                            | 5b                |
| Group of pseudo-primary facies of gentle slopes of Siberian stone pine-larch grass-moss-cowberry forests on podzolized brown and soddy- taiga soils | Larch grass-cowberries forest                                              | 6                 |
|                                                                                                    | Birch-larch cowberries-grass forest                                       | 6a                |
|                                                                                                    | Larch-birch forbs open woodland                                            | 6b                |
|                                                                                                    | **Class of sublithomorphic slope facies**                                  |                   |
| Group of serial facies of steep predominantly northern slopes, of larch grass-moss-cowberries forests on podzolized brown soils | Larch grass-cowberries forest                                              | 7                 |
|                                                                                                    | Birch-larch cowberries-grass forest                                       | 7a                |
|                                                                                                    | Larch-birch forbs open woodlands                                          | 7b                |
|                                                                                                    | Larch with Siberian stone pine grass- cowberries-green-moss forest         | 8                 |
|                                                                                                    | Birch-larch forest with undergrowth of green-moss-herbaceous forest        | 8a                |
|                                                                                                    | Larch-birch with shrubs forbs sparse forest                                | 8b                |
|                                                                                                    | **Class of xerolithomorphic slope facies**                                |                   |
| Group of serial facies of steep predominantly southern slopes, of larch grass forests on soddy-taiga soils | Larch with the inclusion of pine with mixed grass undergrowth              | 9                 |
|                                                                                                    | Larch with birch forbs forest                                              | 9a                |
|                                                                                                    | Larch-birch forbs open woodland                                            | 9b                |
|                                                                                                    | Sparse larch forest with rhododendron Daurian forbs forest                 | 10                |
|                                                                                                    | Sparse birch and larch forbs forest                                       | 10a               |
|                                                                                                    | **Class of subhydromorphic valley facies**                                |                   |
| Group of pseudo-primary facies of drained river valleys, streams, and bottoms of Siberian stone pine-larch-spruce grass-green-moss forests on soddy-taiga and soddy-meadow gleyous soils | Larch-spruce with birch shrubby true moss forbs forests                     | 11                |
|                                                                                                    | Sparse larch-birch with a shrub meadowed forbs forest                      | 11b               |
|                                                                                                    | **Class of cryohydromorphic facies**                                     |                   |
| Group of serial facies of weakly drained catchment areas of reduced larch forests on permafrost swamp and taiga peaty-gley soils | Reduced larch with Siberian stone pine and birch with yernik and Kuril tea grass-Labrador tea forest | 12                |
|                                                                                                    | **Mountain taiga geom of dark-coniferous forests of limited development conditions** |                   |
|                                                                                                    | Class of cryohydrolithomorphic facies                                     |                   |
| Group of primary facies of the planate elevated locations of larch-Siberian stone pine forests on permafrost-taiga peaty soils | Larch-Siberian stone pine moss-subshrub with lichen forest                | 13                |
|                                                                                                    | Birch-larch- Siberian stone pine moss-subshrub forest                      | 13a               |
Table 1. Legend of the landscape map of the the Malyi Khamar-Daban Range.

| Topographic feature (group of facies) | Geosystem                                                                 | Number on the map |
|---------------------------------------|---------------------------------------------------------------------------|-------------------|
| Group of primary facies of watersheds and planate near-watershed surfaces of larch-Siberian stone pine subshrub-grass-true moss forests on soddy taiga with podsolized brown and permafrost-taiga soils | Larch- Siberian stone pine grass-moss-subshrub with lichen shrub forest | 14                |
|                                        | Siberian stone pine, with larch and pine, shrub grass-green moss forest with cowberries | 15                |
|                                        | Birch-larch- Siberian stone pine grass-true moss forest | 15a               |
|                                        | Siberian stone pine-larch-birch with shrub moss-forbs forest               | 15b               |
| Group of pseudo-primary facies of gentle slopes of Siberian stone pine with larch forests on podsolized brown and soddy- taiga soils | Siberian stone pine forests with larch, true moss-grass-cowberries forest | 16                |
|                                        | Birch- Siberian stone pine-larch true moss-cowberries-grass forest         | 16a               |
|                                        | Birch and larch forest with Siberian stone pine and shrub forbs forest    | 16b               |
| Group of serial facies of predominantly northern slopes of Siberian stone pine forests with larch grass-cowberries-true moss forests with sparse undergrowth on the podsolized brown soils | Siberian stone pine and larch with dwarf birch, grass-cowberries-true moss and lichen forests | 17                |
|                                        | Birch-Siberian stone pine-larch forbs-true moss forest | 17a               |
|                                        | Birch-larch forest with Siberian stone pine and shrubs true moss-herbaceous open woodland | 17b               |
| Group of serial facies of predominately southern slopes of dark-coniferous with pine and larch subshrub-grass forests on soddy-taiga soils | Siberian stone pine with pine and larch subshrub cowberries-grass forest | 18                |
|                                        | Siberian stone pine-larch-birch forbs forest | 18a               |
|                                        | Larch-birch forbs open woodland | 18b               |
| Group of pseudo-primary facies of gentle slopes of Siberian stone pine with larch forests on podsolized brown and soddy-taiga soils | Reduced larch-Siberian stone pine and birch yernik grass-Labrador tea-grass forest | 20                |
| Group of serial facies of weakly drained watershed depressions of dark-coniferous forests with birch and larch forests on permafrost swampy and taiga peaty-gley soils | Grass-tansy steppes | 21                |
|                                        | Plots of steppes plowed under crops | 21c               |
| Group of serial facies of steep slopes of mainly southern expositions of low-grass steppes on stony chestnut soils | Low-grass-wormwood lithophilic steppes | 22                |
| Group of serial facies of valley meadow-swamp territories on meadow-chestnut solonetizic soils | Valley grass-sedge-mixed-grass meadows | 23                |

Degree of disturbance of derived geosystems
Table 1. Legend of the landscape map of the Maly Khamar-Daban Range.

| Topographic feature (group of facies) | Geosystem | Number on the map |
|--------------------------------------|-----------|-------------------|
| weakly disturbed                      |           | a                 |
| moderately disturbed                  |           | b                 |
| strongly disturbed                    |           | c                 |

According to the seriality degree, geosystems are divided into primary, located on flat watersheds and near-watershed areas, planate elevated areas; pseudo-primary, confined to gentle slopes; and serial, which are located on steep slopes with outcrops of rocks, as well as in locations with excessive moisture. In the study area, 4 degrees of disturbance of geosystems were identified. Conditionally undisturbed geosystems are located mainly in inaccessible territories. The presence of moderate and strong disturbance geosystems is mainly associated with forest fires, local logging, moderate recreational load and forestry. Areas with the maximum degree of disturbance are confined to agricultural lands and residential territories.

4. Conclusion

Thus, the analysis of the landscape structure of the study area resulted in the identification of significant degree of variability in the geosystems of the Maly Khamar-Daban Range, manifested in the existence of a complex territorial structure of primary and variable states, due to the complex effect of various anthropogenic and natural factors (the influence of biogeocenose location).

The generated landscape map can serve as an informational basis for landscape planning of the territory, assessment of the ecological potential of geosystems, forecasting potential changes in geosystems and other scientific activities in the field of environmental management and environmental protection.

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References

[1] Smagin V N, Ilyinskaya S A, Nazimova D I, Novosel’tseva I F and Cherednikova Yu S 1980 Types of Forests of the Mountains of South Siberia (Novosibirsk: Nauka) p 334
[2] Tsybzhitov Ts Kh, Tsybikdorzhiev Ts Ts, Khubrakova B Ts and Gonchikov B-M N 2006 Soil cover patterns in the Dzhida depression and their representation on the soil map of 1: 500000 scale Eurasian Soil Science 7(39) 705–11
[3] Krasnoshchekov Yu N 2004 The Protective Role of Mountain Forests of the Baikal Basin (Novosibirsk: Publishing House of the SB RAS) p 223
[4] Landscapes of the South of Eastern Siberia: Map 1: 1500000 1977 Ed O P Kosmakova and V S Mikhnev (Moscow: GUGK) p 4
[5] Frolov A A 2015 Geoinformational mapping of landscape variability (exemplified by Southern Cisbaikalia) Geography and Natural Resources 10(36) 99–107
[6] Frolov A A 2016 Mapping of landscapes Southern Cisbaikalia region based on Landsat data Geodesy and Cartography 10 22–9
[7] Vladimirov I N, Sofronov A P, Sorokovoi A A, Kobylkin D V and Frolov A A 2014 Structure of vegetation cover in the western part of the Upper Angara depression Geography and Natural Resources 2(35) 143–51
[8] Landgrebe D and Biehl L 2011 An Introduction and Reference for Multispec Version 9.2011 (West Lafayette, Indiana USA Purdue University) p 189
[9] Vladimirov I N 2018 New methodical approaches to mapping of geosystems (on the example of Baikalian Siberia’s geosystems Geodesy and Cartography 7(79) 23–34
[10] Kuz’menko E I, Frolov A A and Silaev A V 2018 Geoinformational Mapping of Landscapes in the Northwestern Part of Western Siberia Using the Hansen Mosaic Dataset Geography and Natural Resources 2(39) 175–81