Anthropogenic Transformation of Vegetation and the Effectiveness of its Protection in the System of Protected Natural Territories on the Example of the Altai Krai

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Abstract. The plant cover of the Altai Krai experiences significant anthropogenic pressures. The main factors of anthropogenic transformation of ecosystems are land plowing, grazing, haying, felling, recreation, fires, etc. All of them lead to the decreased species diversity, decreased biological productivity, and degradation of biocenoses. Phytoecological mapping of vegetation degradation makes it possible to assess the environmental consequences of anthropogenic activities at local and regional levels. The results of the study can be used to determine and predict the status of biogeocenoses. Ecological monitoring will allow for planning activities for the rational use and protection of natural resources. We have mapped the Altai Krai and identified four territorial complexes with varying degrees of the transformation of vegetation cover – weak, moderate, healthy, and very strong. We assessed the effectiveness of vegetation protection in the system of protected areas. In areas with an extreme degree of transformation, the location of protected areas is 2.6%. The types of landscapes for the creation of protected areas are proposed.

Keywords: Anthropogenic transformation of vegetation · Specially protected natural areas · Phytoecological mapping · Sustainable land management

1. Introduction
Vegetation is an indicator that responds to the stressful effects of anthropogenic factors [1, 15]. Various parameters and scales are used to identify the stage of vegetation transformation, including phytoecological mapping [5, 6, 7, 11]. Phytoecological maps contain information on the current state of the vegetation cover of the territory and the degree of change in zonal-typological and territorial complexes of vegetation. They reflect the effects of human exposure to the environment [2, 3, 4].

The plain part of the Altai Krai is the most agriculturally developed area. The development of virgin and fallow lands led to the plowing of a significant number of steppe ecosystems. Natural fodder land is subjected to intensive grazing. This contributes to a change in natural plant communities. Species diversity decreases; the forage value of the grass stand and its biological productivity decrease. Many plant communities are at a failure stage. The restoration of such degraded areas requires significant time and economic costs.

The main factor in the anthropogenic transformation of the lowland territories of the Altai Krai is plowing, which was especially intense during the development of virgin and fallow lands. The zonal types of steppe ecosystems that occupied upland habitats were almost destroyed [14]. Slightly inclined surfaces, which were also plowed, were severely damaged.

Sites of natural vegetation were preserved in small areas by negative landforms (barren, lake-bog,
salt marshes, hollows, slopes of hills, river valleys, and beams). They are subjected to intense anthropogenic stress. Many phytocenoses are endangered. Forest ecosystems suffer from clear-cutting, fires, and recreation [14].

Dryland and floodplain meadows undergo grazing during overgrazing and haying. Additionally, the steppe zone of the studied region borders with desert regions, affecting the composition of its vegetation cover.

In the Altai Krai, there are communities of dry and desert steppes on the northern border of their distribution and unique halophytic desert communities. They are also subjected to anthropogenic stress and require the introduction of a protective regime.

In this regard, phytoecological mapping of the study area, as well as the identification of the effectiveness of vegetation protection and measures for the restoration and protection of natural ecosystems, are of particular relevance.

2. Materials and Methods

The vegetation cover of the Altai Krai is subject to a powerful anthropogenic impact. To assess the dynamics and degree of change in vegetation, we conducted a geobotanical study of critical areas with subsequent phytoecological mapping. For mapping, such parameters as phytocenotic diversity, occupied area, nature of the change in phytocenoses, productivity, etc. were used.

The study of the vegetation cover included assessing the state of forest, meadow, steppe, and bog ecosystems of the Altai Krai. Anthropogenic degradation of each type of vegetation was detected using standard geobotanical descriptions, ecological scales, ecological mapping, and comparison with reference sites [9, 10].

Route reconnaissance surveys of the territory allowed to identify the zonal features of natural conditions and vegetation cover and identify critical areas for further detailed study. At key sites, the species composition of phytocenoses, projective cover and abundance of species, longline composition, and the nature of the spatial distribution of species were described. To obtain the geobotanical features of phytocenoses, a uniform study of key sites was carried out by laying down a series of sample plots on the primary relief elements and systematic recording of vegetation changes in ecological profiles.

The study of the succession processes of vegetation of the studied region under anthropogenic factors and a comparison of the disturbed communities with reference sites to different degrees allowed to identify areas occupied by indigenous, derivative, and cultivated communities. The values of the index of anthropogenic transformation of vegetation cover within individual administrative territories were determined to identify the stage of anthropogenic change of ecosystems.

The anthropogenic transformation index was determined by the following formula [5]:

\[ T = \frac{(S_s + S_a)}{S} \times 100\% , \]

where \( T \) – the index of anthropogenic transformation, \( S \) – the total area of the territorial complex, \( S_s \) – the site of transformed vegetation, \( S_c \) – the cultivated vegetation area.

We adopted the following ranking of the values of the vegetation transformation index (table 1).

| Transformation index | Degree of transformation |
|----------------------|-------------------------|
| <10%                 | very weak               |
| 10%–30%              | weak                    |
| 31%–50%              | moderate                |
| 51%–70%              | strong                  |
| >70%                 | very strong             |

Source: [5].
3. Results and Discussion

Using geobotanical descriptions of plant communities and indices of their anthropogenic transformation, we gave a phytoecological assessment of administrative districts and compiled a phytoecological map of the Altai Krai.

We identified four types of vegetation degradation during the study, which differ in the degree of disturbance of the vegetation cover and allow revealing the laws of its transformation (table 2).

In the Altai Krai, no areas with a fragile degree of vegetation transformation were identified. A weak degree of vegetation transformation (10%–30%) was detected in five districts of the Altai Krai. A moderate degree of vegetation transformation (31%–50%) is characteristic of the territorial complex, covering 18 districts in the left-bank of the Priobsk forest-steppe, forest-steppe of the Pre-Altai plain, and partially the Kulunda Steppe.

The 25 most economically developed districts are marked with a substantial anthropogenic transformation of vegetation (51%–70%) and occupy parts of the Kulundinskaya Steppe and left-bank and right-bank territories Priobsk forest-steppes.

An extreme degree of vegetation transformation (71%–90%) is characteristic of the 12 administrative districts of the Altai Krai.

| Transformation Index, % | Number of districts | Area of the district, thousand km² | % of the total area of the Altai territory |
|------------------------|---------------------|-----------------------------------|------------------------------------------|
| <10                    | ~                   | ~                                 | ~                                        |
| 10–30                  | 5                   | 15.7                              | 9.34                                     |
| 31–50                  | 18                  | 61.3                              | 36.49                                    |
| 51–70                  | 25                  | 62.3                              | 37.08                                    |
| >70                    | 12                  | 28.3                              | 16.85                                    |

**Source:** Compiled by the author.

Thus, in 23 administrative districts (46% of the Altai Krai), vegetation is marked with a weak and moderate transformation degree. In 37 districts (54% of the region), vegetation has significantly changed.

Administrative areas in which vegetation transformation is above 71% should be considered areas of environmental disaster. In such areas, it is necessary to develop a system of measures to restore vegetation cover. A significant reduction in indigenous vegetation area contributes to a decrease in species diversity and the disappearance of habitats of rare species.

The study showed that all types of phytocenoses are marked with high grass stand degradation rates and a decrease in biological productivity under the influence of anthropogenic factors. A program should be developed to monitor the state of vegetation cover and measures for its protection to preserve plant communities.

Currently, the protection of the vegetation cover in the Altai Krai is carried out mainly within the framework of specially protected natural territories [SPNT]. The system of specially protected natural territories [SPNA] in the region is represented by one protected area of national significance (State nature reserve ‘Tigirekskij,’ an area of 406.93 km²) and 107 protected areas of regional importance (an area of 853.37 km²), including two nature parks, 38 state nature reserves, and 67 natural monuments. It covers 5.3% of the Altai Krai [12].

Specially protected natural areas are unevenly located in the Altai Krai. In areas with the weak transformation of vegetation, they occupy only 7.4%, in areas with the moderate transformation of vegetation – 6.1%, and in areas with the strong transformation of vegetation – 4.5%. The vegetation in areas of an ecological disaster in protected areas is protected only at 2.6% of the area (table 3).
Table 3. The characterization of SPNT and their distribution in the Altai Krai.

| Transformation index | Degree of transformation | Characteristic SPNT area, thousand km² | % of the total area |
|----------------------|--------------------------|---------------------------------------|-------------------|
| <10 %                | Very weak                | –                                     | –                 |
| 10–30 %              | Weak                     | 1,162.83                              | 7.4               |
| 31–50 %              | Moderate                 | 3,740.04                              | 6.1               |
| 51–70 %              | Strong                   | 2,796.98                              | 4.5               |
| >70 %                | Very strong              | 747.67                                | 2.6               |

Source: Compiled by the author.

Currently, all reserves in the Altai Krai are complex. Some of the resources do not have detailed vegetation features because they previously belonged to zoological or hydrological reserves. Most of the funds are organized on the territory of ribbon pine forests. Birch pegs, steppes, valley forests, uplands, floodplain meadows, and swamps are poorly protected.

In the Altai Krai, there are phytocenoses requiring protection and included in the Green Book of Siberia [8]: 12 – steppe phytocenoses, 10 – forest, 4 – meadow, 8 – floodplain, 2 – high mountain, and 4 – halophyte communities. The analysis of the degree of coverage of rare plant communities by the SPNT system has shown that only 80% of phytocenoses are protected.

Birch forests with *Brachypodium pinnatum* (*Betula pendula – Brachypodium pinnatum + Rubus saxatilis*) and floodplain forests with *Salix alba*, *Populus nigra* and *Populus alba, Populus laurifolia* are not protected. The protection of the tape and Priobsky pine forests is well organized.

Of the steppe communities, feather grass meadow steppes (*Stipa pennata*), desert steppes (*Artemisia gracilesens + Festuca valesiaca*), and feather grass petrophytic steppes (*Stipa Orientalis*) are not protected.

Floodplain and upland meadows are practically not protected.

In the Altai Krai, there are at least 2,000 plants, about 400 species of mosses, and a significant number of lichens and algae. The Red Book of the Altai Krai [13] has 202 species of plants that need protection, including 11 species of mushrooms, 23 species of lichens, ten species of mosses, 15 species of ferns, two species of plunders, and 141 species of angiosperms [13].

By the number of rare species, all reserves can be divided into four groups:

- Group 1 – sanctuaries containing more than 10% of rare plant species;
- Group 2 – sanctuaries protecting 6%–10% of rare plant species;
- Group 3 – sanctuaries protecting 2%–5% of rare plant species;
- Group 4 – sanctuaries protecting 2% of rare plant species.

We distinguished the following types of landscapes that underwent a less anthropogenic transformation and where it is possible to plan the creation of protected areas:

1. Swamp-lake basins and their systems, low saline plains along with the belt forests. They are marked with communities of shrub halophytes, chievniki, complex solonetzic steppes, and coastal-aquatic vegetation.
2. River floodplains. They are occupied by complexes of forest, meadows, marsh and shrubby vegetation, floodplain meadows, and swamps.
3. Beam systems. The vegetation is represented by a combination of steppes, small-leaved grassy forests, and complex meadow-bog vegetation.
4. They aligned the watershed spaces of the forest-steppe zone. They are marked with birch spikes, meadows, true steppes, steppe, and post-forest upland meadows.
5. Separate hills and small hills. Various types of steppes represent the vegetation.
6. Tape burs. Stepped pine forests, grassy sandy steppes, solonchak meadows, and birch boggy
forests are recommended for protection in various districts of the region.

4. Conclusion

Thus, phytoecological mapping provides an integrated assessment of the current state of vegetation and its anthropogenic transformation. Geobotanical maps should be used when developing a program for the rational use of natural resources.

The protection of vegetation cover can be achieved by increasing the area of specially protected natural areas, especially in areas of ecological disaster.

To measure natural vegetation protection and restoration, it is necessary to allocate reference areas for each zonal and intrazonal vegetation.

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