Preservation of steppe landscapes in the structure of agrolandscapes of the Republic of Khakassia

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Abstract. The article presents the results of longstanding field studies (2000-2020) of steppe vegetation and demutation processes of fallow lands in the Altai region of the Republic of Khakassia. The aim of the work is to identify and determine the area of steppe landscapes and demutation areas in the structure of the lands of the Altai region. For this, a land use map of the Altai region was created, the areas of land occupied by steppe vegetation and fallow lands at different stages of restoration were calculated, demutational areas susceptible to overgrowing with trees and shrubs were identified. Based on geobotanical researches, cartographic materials, visual interpretation of Sentinel-2 satellite images of the visible L2A range (2018-2020), a GIS-project was created, including a cluster of raster data, thematic vector layers: water bodies, agricultural lands, vegetation, etc. It allows you to visualize information about the state and use of agricultural lands and vegetation in the form of maps of different thematic scope. It was searched out that the part of steppe landscapes in the total area of the Altai region is 32.2%. In the main, in arable sandy steppes that are not zonal for Khakassia have been preserved. True large bunchgrass and meadow steppes have been preserved in separate fragments and represent all stages of anthropogenous fracturing (various pasture modifications of these steppes). In the study area in the structure of agricultural lands 56860 hectares of agricultural lands belongs to abandoned lands at different stages of restoration, and only 20% postagrogenic lands of which are at the IV stage of restoration (compact-tussock or truly cespitous grasses). The process of restoration of steppe vegetation is accompanied by overgrowing with Ulmus pumila L.

1. Introduction
The general area of the steppes, located within steppe and forest-steppe zones of Khakassia, were plowed up in the 50s-60s of the 20th century. So, according to A.V. Kuminova, agricultural development of the steppe zone amounted to 40.3% of its total area (more than 800 thousand hectares of land were involved in plowed field) [1]. The remaining fragments of steppe landscapes were actively used as pasture-lands. For this reason, one of the main factors in the steppe communities transformation, along with the excessive ploughness of the territory, was pasture digression. The problem of steppe pastures degradation in Khakassia was clearly evident already in the 1970s – 1980s during a geobotanical screening of all farms of the Republic. According to the results of research by G. T. Kandalova [2], pasture digression includes four stages of overgrazing (reasonable, intense, excessive and failure), common for Khakassia and the South of Siberia. Starting from the second stage, xerophytization of the vegetation cover is clearly evident, the role of dwarf shrubs (Artemisia
frigida Willd) and shrubs (Caragana pygmaea (L.) D.C.) increases. Then, seed renewal decreases, the species composition of phytocenoses (primarily the miscellaneous herb group) and the age-specific spectrum of cenopopulations become impoverished, and the rhythmic of seasonal development changes. The structure in the steppe communities becomes simpler, the projective cover, the phytomass producing capacity, and the proportion of dead grass and ground litter decrease. By the early 1990s, the share of agricultural lands used in the Republic of Khakassia had significantly decreased, and the reclamation processes of grassland vegetation and vegetation of hayfields and pastures began. For 10–15 years, the overgrazed grass stand of steppe communities returns to steady-state conditions, similar to the initial (autochthonous) [2]. The reclamation process of abandoned lands requires much more time (20–25 years), however, the specificity and speed of progressive successions depends on a fairly wide range of factors: climatic parameters, features of micro- and macro-relief, the existence of a full valued source of steppe species seeds, etc. [3]. At present time, the self-healing process of the background steppe vegetation of Khakassia requires new detailed scientific research, as the lands turned out of plowable turnover are overgrown with a tree species of little value and rather resistant to various influences (arid conditions, injurious insects, pruning, etc.) – as Siberian elm (Ulmus pumila). Most of the timber stands formed naturally on the former agricultural lands in other regions of Russia, are quite valuable, as they are overgrown with valuable small-leaved and needle-leaved hardy-shrub species. Elm groves forming in Khakassia act as a source of ‘biological pollution’ and an object of increased fire hazard (constantly icing up branches facilitate to the accumulation of dead standing trees). A number of authors believe that the agroforestry ecosystems formed in such cases significantly increase the productivity of such lands as pastures, as a better small scale climate (shade for grazed animals) and more supportive environment than in the open steppe for the growth of various types of grasses and the uprising of ecological niches as a habitat for steppe animals, birds and useful entomofauna are formed here [4]. However, in this case, the progressive succession of the abandoned lands changes its character.

Purpose of the work is: to identify and determine the area of steppe landscapes and areas with a regenerating steppe grass stand in the structure of the lands of the Altai region. Research objectives are: to create a land use map of the Altai region, to calculate the area of lands occupied by steppe vegetation and fallow lands at different stages of restoration, to identify demutational areas prone to overgrowing with trees and shrubs.

2. Materials and Methods

The preservation evaluation of the steppe landscapes in the structure of agricultural areas of the Republic of Khakassia is given on the example of the Altai region of the Republic of Khakassia. The study area is located within the Koibal steppe of the South-Minusinsk depression. The surface topography is a high constructional plain with separate low-level range of hills and small inland lake basins, mainly with absolute relief elevations from 260 to 580 m above sea level. The western part of the region is characterized by eolian forms – hillocks and sand dunes, alternating with deflation basins and elongated depressions occupied by vleis. The duration of the period with temperatures below 0 ºC is 85–110 days on average. During the period of dynamic plants growth (May – July) there are rain falls from 170 to 210 mm, and in general for the year - from 370 to 490 mm. The duration of the frost-free season varies from 105 to 115 days. The dryness index (the correlation between the sum of the daily mean temperatures above 10 ºC and the amount of precipitation in May – July) is 1.9–1.7 (arid – insufficiently humidified). The prevailing wind direction is southwest [5]. The region’s hydrographic network is poorly developed and is determined by the large boundary transit rivers Yenisey and Abakan. There are many small lakes in the southern and southwestern part of the region (along the buried channel of the Yenisey). The larger lakes Chalaskol, Kharykhkol, Morykhkol, Stolbovoe, etc. are located within the Sorokaozernaya steppe in the Sorokaozerky natural limit (a wetland).

According to the agrolandscape classification, the territory is located within the East Siberian province of the steppe area in the steppe interfluval Abakan-Yenisey agrolandscape territory. Agroecological land group is wind-eroded steppe land.
Zonal soils are light and middle loamy ordinary chernozems on loess loams, sand clays, sands and weakly-developed deposits [6]. In the southwestern and western parts of the region, flinty soils and the solonetz-solonchak type soils are widely developed. On the hillsides and top-stones of cuestas are often chipped with outcrops of bedding rock. The Altai region belongs to the natural steppe area, therefore, the vegetation is mainly represented by small-sod and coarse-sod real steppes with their digression and chipped varieties. The vegetation cover was examined using generally accepted geobotanical methods [7]. The geobotanical description of the vegetation cover included the following information: floristic composition, projective cover, characteristics of the spatial (vertical and horizontal) structure of phytocenosis, phenophase, plant vitality. Over the years of research, 640 geobotanical descriptions have been completed. The stages of restoration of fallow vegetation are given according to G.T. Kandalova. [8]. Field data were spatially positioned using GPS Garmin Etrex.

To create a GIS-project for the study area, the ArcMap 10.1 program was used. The digitization of vector layers was carried out on the basis of the analysis of raster topographic maps of different times (M 1: 500000, M 1: 2000, M 1: 100000), a paper map (agricultural) of the Altai region of the Republic of Khakassia, 1992 (M 1: 100000), electronic public cadastral map of the Russian Federation for the Altai region, multispectral satellite images of the growing season (end of July - September) from 2019 to 2020, Landsat 8 panchromatic and visible range (15 m and 30 m) (USGS, https://earthexplorer.usgs.gov) and Sentinel L2A (10m) (URL: https://scihub.copernicus.eu). On the basis of 65 selected satellite images from 2019 to 2020, their catalog and mosaic were created, color rendition and georeferencing to the project coordinate system were corrected.

3. Results Discussion
The WGS 1984 UTM Zone 46N coordinate system, the Mercator / WGS84 projection, was selected when creating a geoinformation project. The formed database includes raster materials (maps and catalog of satellite images) and vector layers (water bodies (rivers, canals, lakes), roads, borders of districts and village councils, forest belts, agricultural lands, settlements, etc.). The attributive information of the areal vector layer «agricultural land» contains data on the types of agricultural lands, the stages of overgrowth, the stages of the fallow restoration, etc. The main indicators included in the attributive table of the areal vector layer «vegetation» are: type of vegetation, dominant plant communities, number of species, total projective cover, average height of herbage, etc.

The database and GIS-project illustrate the current state and use of agricultural lands, including natural forage land (pastures and hayfields) of the Altai region. The area of the Altai Municipal District is 173.61 thousand hectares, where 94.4% of the district's territory is agriculturally used areas, and about 62% is agricultural lands (plantations). In the studied area in the past, oat-feathergrass and large-wormwood-feathergrass steppe communities were developed with a dominance of Stipa capillata L., Helictotrichon altaicum Tzvel, Stipa pennata L., with a rich species diversity of the miscellaneous herbs and legumes groups [3]. However, due to the almost full ploughness of the territory, it is possible to judge about these initial types of vegetation only by the particular preserved areas. In the northeastern part of the region, between the settlements of Letnik and Altai, forb-pinnate-feathergrass steppes have been preserved in combination with graminous-forb meadow steppes (Figure 1). On the rocky outcrops of the cuesta top-stones and in their upper parts of the southern hillsides, areas of petrophytic-forb steppes with Cymbaria dahurica L. and Eritrichium jenisseense Turcz survived.

The main part of the preserved solid masses of steppe landscapes is located in the southwestern and western parts of the region on old-alluvial sand deposits. Sandy coarse-cespitose-rhizomatous steppes are widespread here, mainly represented by caragana-wormwood-graminaceous and forb-wormwood-graminaceous steppe communities. The southern hillsides aspect at the sandy hillocks are occupied by wormwood-graminaceous-forb steppe communities with a projective cover of no more than 40%. A significant acreage occupied by formation group of sand steppes is currently allotted for the coal mining. The total area of land withdrawn for the ‘Razrez Arshanovsky Coal Mine’, of primary, is over 125 km².
Figure 1. Steppe communities in the structure of agrolandscapes of the Altai region.

Improved haylands and pastures have not been used as intended for many decades and, therefore, no measures for periblastic and radical amelioration improvement have been taken on such areas. Most of them now represent real coarse-cespitose-wormwood-gramineous-feathergrass steppes, often with the participation of Caragana rygmaea (L.) DC. On the southern hillsides aspect of gently rugged terrain forms, real small-cespitose-wormwood-forb-gramineous-grass steppes are observed. The total area of such land today is 6360 hectares (3.7% of the total area of the district).
The anthropogenic transformation of steppe landscapes, which were used as pastures, noted in the 60s-70s, is in a situation at present time. Steppe communities near settlements, where uncontrolled and unregulated grazing of animal stock is realized, are extremely destroyed. In such areas, sedge-wormwood-serpentine-grass and wormwood-gramineous-grass associations with a low projective cover (no more than 55%) and a small number of species (no more than 14 species per 100 m²) are widespread. The grass stand is dominated by: *Cleistogenes squarrosa* (Trin.) Keng, *Artemisia frigida*, *Artemisia scoparia* Waldst. et Kit, *Carex duriuscula* (C.A. Mey.), *Potentilla bifurca* L. The total area of land occupied by steppe vegetation is about 55100 hectares (32.2% of the total area of the Altai region).

At present, 56860 hectares of agricultural land (33.2% of the total area of the district) are abandoned lands at various stages of restoration. For the cultivation of agricultural crops, only 19662 hectares are used [9]. Therefore, in the study area, demutation processes (the reversion of steppe landscapes to the autochthonous (baseline) condition) were activated. According to our estimates, about 1200 hectares of postagrogenic lands are at the IV stage of restoration (the stage of compact-tussock or truly cespitous grasses). The grass stand consists of *Stipa capillata*, *Koeleria cristata* (L.) Pers., *Leymus ramosus* (Trin.) Tzvel., *Cleistogenes squarrosa* (Trin.), etc. At the stage of rhizomatous grasses (II stage of recovery) are about 12400 hectares. In this case, the grass stand is composed of *Elytrigia repens* (L.) Beauv., *Bromopsis inermis* (Leyss.) Holub., on drier and solonetzic soils is composed of *Leymus ramosus* (Trin.) Tzvel. However, more than 65% of such abandoned lands are currently overgrown with *Siberian elm* (*Ulmus pumila*). According to research by M. A. Martynova [10] and to our observations, the process of restoration of abandoned lands up to stage IV in such areas slows down, especially where the density of the timber stand is more than 0.3. Perhaps this is due to the accumulation of leaf litter, shading and other factors. As a result, rhizomatous grasses are dynamically vegetated (*Bromus inermis* Leyss., *Leymus ramosus*, *Calamagrostis epigeios* (L.) Roth, *Melilotus officinalis* (L.) Pall., and young forest of *Ulmus pumila* is overgrown.

4. Conclusion
The steppe landscapes preserved in the Altai region are exposed to local anthropogenic loads and in this connection, in some areas digression processes expressed in a decrease in species diversity, a simplification of the structure of the grass stand and a decrease in projective cover are observed. As a result of the crisis in the agro-industrial complex of Khakassia, a significant proportion of the cultivated areas in the Altai region were transferred to abandoned lands and haylands, where the process of restoration of the autochthonous steppe is now being observed. The observed process of recovery of abandoned lands takes place in conditions of overgrowing with *Siberian elm* (*Ulmus pumila*). In this case, the rate of demutation processes slows down, and the period of the rhizomatous stage of recovery is lengthened. The developed geoinformation project provides an opportunity to view current satellite imagery data, to create specialized thematic maps of different levels of detail, to analyze data on agricultural lands, etc. The research results can currently be used to inventory the use of agricultural lands in the Altai region of the Republic of Khakassia, and for increasing situational awareness and making management decisions.

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