Vegetation cover dynamics of the Mongolian semiarid zone according to multi-temporal LANDSAT imagery (the case of Darkhan test range)

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Abstract. At present much attention is given to the spatio-temporal dynamics of plant communities of steppes to assess their response to the current climate changes. In this study, a mapping of a selected modeling polygon was carried out on the basis of data decoding and field surveys of vegetation cover in the semi-arid zone. The resulting large-scale map of actual vegetation reflects the current state of the vegetation cover and its horizontal structure. It is a valuable material for monitoring of changes in the chosen area. With multi-temporal satellite Landsat imagery we consider the vegetation cover dynamics of the test range. To analyze the transformation of the environment by the climatic factors, we compared series of NDVI versus the precipitation and of NDVI versus the temperatures. Then we calculated the degree of correlation between them.

Keywords: desertisation, semiarid zone, vegetation cover transformation, succession, Landsat, mapping of vegetation.

1 Introduction
During the last decades the problems of desertification and transformation of the environment are still relevant. Climate changes and irrational nature management lead to the transformation of the vegetation cover. During the last decades an increased grazing pressure on ecosystems has changed nature balance because of higher vulnerability of semiarid and arid ecosystems, entailing their degradation and desertification [1].

Mongolia has a unique complex of natural and climatic conditions and inimitable landscapes. Which have been causing interest for the scientists of different disciplines for ages. The steppes are sensitive to the effects of anthropogenic factors and climate change. They serve as an indicator in the study of spatio-temporal dynamics of landscapes and their response to the current climate changes. Spatially-structural studies of vegetation are particularly important, especially for the monitoring and are presented as an essential condition of an ability to predict the dynamic processes in the landscape sphere.

The aim of this work is to study the structure and dynamics of vegetation of steppe ecosystems of semi-arid zone of Northern Mongolia as in the case of Darkhan testing range. During the study a map current vegetation model site was compiled, the spatial dynamics of vegetation was revealed using the multi-temporal satellite imagery and the correlation values of NDVI with precipitation and temperature was analyzed.
2 Materials and methods

2.1 Characteristics of the study area
To study the dynamics of degradation and desertification processes of arid lands we have founded a number of testing ranges in different latitudinal zones (51-44° N) on the meridional Baikal Gobi transect (105-107° E). The site, which is located 3 km far to south-west of the city of Darkhan, 19.16 km² in area, was selected as a testing range (Figure 1). The bigger part of the site is situated in the portioned slopes of small-altitude Orkhon-Kharaa River interfluve (absolute altitude marks are 810-870 m.) and partially at the eastern part of Bayan-Daba mountain foot and on the second Kharaa River terrace above the flood plain. According to botanical-geographical zoning, this area refers to the Mongolian steppe province of the Srednehalhaskaya Subprovince of the Central Asian (Daurian-Mongolian) subregion of the steppe region of Eurasia [2]. The climate of dry Mongolian steppes is characterized by strongly pronounced continentality which is caused due to the location of the country in the centre of Eurasian mainland. This type of climate is formed under the influence of a whole number of factors. The location of dry steppes, 50º N further southward, is conductive to a great amount of solar radiation during the vegetation period. But isolation from the main moisture sources leads to climate aridisation. With increase of climate aridity precipitation deficit increases [3], which affects the composition and quality of phytocenosis.

Figure 1. The Darkhan testing range.

2.2 Satellite data
To obtain basic information on the spatial organization of ecosystems satellite imagery from Landsat (sensor TM, ETM +, OLI) with a spatial resolution of 30 m were used (available on the website http://glovis.usgs.gov).

To assess the spatial-temporal dynamics of vegetation we used the Landsat imagery, obtained at approximately the same period of the phases of vegetation development: September 20, 2000 September 10, 2002 and August 31, 2013 and July 14, 2014. Processing was carried out using a standard method of classifying images without training ISODATA. The combination of multi-temporal vector layers for each category of vegetation and detection of changes were implemented through the ArcGIS software package.

To assess the current status of vegetation cover we used as a basis the Landsat 8satellite image from 14 July, 2014. On the initial stage the image was classified into 20 classes. Then we combined them into corresponding vegetation types based on the field studies. For each class we made sampling
of pixels brightness values of each image channel belonging to some or other groups of plant communities. At the final stage of creation of a geobotanical map we conducted generalization of the image, i.e. the combination of the pixels in uniform contours.

We used 16-day composites of NDVI (product MOD13Q1 [4]) to assess the correlation between rainfall and temperature [5].

To highlight the different ecotypes (sloping surfaces, gullies and ravines systems, etc.) we used materials of radar topographic mapping (SRTM srtm.usgs.gov).

### 2.3 Geobotanical data

Geobotanical study was conducted on the basis of original materials collected during the field work.

In total, according to standard methods, 83 full geobotanical descriptions were performed, 3 geobotanical routing profiles from 2 to 4 km length were conducted, geobotanical monitoring areas were laid (10x10 m), biological productivity of characteristic phytocenoses was defined. Lines of route profiles were laid with the seizure of the most different clusters of the satellite image.

For primary sorting of the descriptions of phytocenoses and their processing using ecological scales the IBIS program was used. 7% of the descriptions were rejected. Summary tables of the species composition, geographical and ecological spectrum were obtained. The types of plants were ranked on scales of moisture and richness, soil salinity.

While identifying the species composition of the vegetation we used abstract of flora [7] and key to identification of plants of Mongolia [8] and Buryatia [9].

### 3 Results

In the analysis of vegetation the array of geobotanical descriptions was differentiated by the principle of uniformity of floristic composition, the prevailing types of horizontal addition of communities, the uniformity of habitat into several groups. Obtained a set of communities which are similar according to the composition and structure are defined as coenoflore, which are comparable in volume to the units of the average rank of vegetation classification, in particular to formations. To highlight the associations, the descriptions were subjected to table processing using the dominant-determinant principle.

Mapping of the selected testing range was carried out on the basis of the data decoding and field surveys. The resulting large-scale map of actual vegetation (M 1:20000) reflects the current state of vegetation cover and its horizontal structure. It is a necessary material for the monitoring of the changes in the chosen area (Figure 2).

![Figure 2. Map of vegetation Darkhan testing range.](image-url)
Almost everywhere the current vegetation cover is presented by modified communities, many of them are the stages of degradational successions, formed as a result of constant (seasonal and year-round) cattle grazing. Because of the overgrazing the vegetation of these landscapes is on the stage of middle digression. Vegetable species are in bad vital condition. General projective herbage doesn’t grow under 40%, while the average value is 15-20%. Assessment of the species coenotic value was made basing on activity of the species. Comparative analysis of middle projective herbage showed, that 4 species have maximal coenotic value: Carex duriuscula (C.A. Meyer), Caragana microphylla (Pall.) Lam., Artemisia frigida (Willd), Potentilla acaulis. Their middle projective herbage is quite big (6-10%). It is established that coenotic value of these species considerably change in the communities of different types of relief.

In the process of mapping in this model range 9 homogeneous (76.8% the occupied territory) and 7 heterogeneous cenoses were identified. The homogeneous type of vegetation is characteristic of sloping areas in the foothills and leveled tops advanced ridges and also on their feet.

The NDVI vegetation index characterizes the content of photosynthetically active biomass. To analyze the interannual dynamics of vegetation depending on climatic factors, we compared the values of NDVI of Darkhan testing range, averaged for the vegetation period (May-September), with rows of precipitation, summed over August and September for each year (Figure 3).

![Figure 3](image-url)  
**Figure 3.** The time series of NDVI, precipitation and temperature data.

Correlation analysis revealed that the highest correlation coefficient was observed for NDVI and precipitation total for the August - September and equals to 0.71. The correlation coefficient of NDVI and precipitation amounts during the vegetation period is equal to 0.36, the correlation of NDVI and annual precipitation is equal to 0.41. However, the correlation between NDVI and average temperatures during the summer and autumn periods is very low and does not exceed 0.2. The greatest amount of precipitation falls on was during 2000, 2007, 2009 and 2013. The least amount of precipitation occurs in 2002 and 2012.

To assess the spatial dynamics of vegetation the images for moist years - 2000, 2013, and the dry years - 2002 and 2014 (Figure 4) were used. Unfortunately, due to the high percentage of cloud cover was not available pictures for 2007, 2009 and 2012. They could give the most complete picture of the dynamics of vegetation distribution.
Figure 4. Models vegetation testing range on the results of the interpretation of satellite images and the histogram distribution of classes by pixels.

The results of analysis of satellite imagery have identified that the greatest changes in the vegetation areas are observed in Cleistogenes and Caragana communities. Thus, in dry years the area occupied by Caragana communities significantly increased in comparison with the humid years - from 18.6% in 2000 to 24.3% in 2002 and 20.3 percent in 2013 to 24.3% in 2014, while Cleistogenes community reduced the area from 15.7% in in 2000 to 11.6% in 2002 and 14.2% in 2013. to 9.8% in 2014 (Table 1). The intensity of growth Cleistogenes communities is closely linked to the presence or absence of precipitation. In humid years their condition is improved and the amount of biomass increases. During droughts growth communities is severely depressed [10].

|                | 2000 | 2002 | 2013 | 2014 |
|----------------|------|------|------|------|
| Potentilla communities | 15.6 | 14.9 | 15.5 | 14.3 |
| Artemisia communities | 12.2 | 13.3 | 12.2 | 11.0 |
| Caragana communities | 18.6 | 24.3 | 20.3 | 24.3 |
| Stipa communities | 20.1 | 17.1 | 18.0 | 19.9 |
| Cleistogenes communities | 15.7 | 11.6 | 14.2 | 9.8  |
| Carex communities | 17.8 | 18.9 | 20.4 | 20.6 |

Table 1. The ratio of the area of plant communities of the model range in percent.

Caragana has a high stress tolerance to drought, however, it is an invasive species, able to occupy the vacated niche. In addition, it is considered that the invasion of adventitious species is one of the leading factors in the transformation of natural ecosystems [11]. Potentilla and Artemisia frigida community remain relatively stable.

Another factor affecting the degradation of plant cover is a high anthropogenic load. According to the Mongolian State National Statistical Committee of the territories of Selenge aimag and Darkhan-Uul in the first decade of this century, there is a steady trend of increasing of the number of farm animals [12]. Express surveys of herdsmen who keep their farms within the territory of Darkhan testing range modeling were conducted. It appears that about half of them migrated here (closer to the main markets for livestock products) with their herds in the 2000s from other peripheral aimags of
Mongolia: western (mostly) and southern - Gobi [12]. Increasing overgrazing pressure leads to the vegetation cover degradation and its change. Pasture desertification acquires the features of an irreversible and progressive character in terms of the dry multi-year period.

4 Conclusions

Based on the use of remote sensing data for the first time was examined dynamics of various areas of steppe plant communities on the testing range of Northern Mongolia. Large-scale map of actual vegetation based on remote sensing methods, reflects the current state of cenotic diversity and condition of steppe ecosystems. The results demonstrate a close correlation relationship between the state of the vegetation cover and the amount of precipitation. In drought conditions, the most valuable in fodder grasses partially drop out grass. Their place is taken by digress-active invasive species. Climate-caused vegetation changes occur on the background of increasing anthropogenic load – increase in the number of livestock.

It was possible to assess the current state of vegetation with high precision using information methods. Based on the data of field descriptions of ecotope distribution of steppe ecosystems was identified and the classification of the steppes was carried out. On the basis of processing of satellite images retrospective assessment of the dynamics of vegetation was obtained. The combination of remote sensing and field research methods allowed more efficiently and accurately assess the condition and character of the use of steppe ecosystems.

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