Geoecological estimate of grassland use in the desert and semi-desert zone of the Republic of Kalmykia

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Abstract. In the Republic of Kalmykia, natural grassland and hayfields is a pivotal structural component of the ecosystem occupying 2/3 of the total regional land available. Developed pastoralism mirrors the representativeness of the region in terms of socio-economic and environmental issues of arid territories. Intensive use of grassland in the last century led to the development of pasture digression that is regarded not only as a key integral component, but also a desertification factor. The major livestock farms are located in the most arid regions of the republic, which entails the risks of growing degradation and desertification processes. To encourage effective and sustainable economic activity, greater clarity is needed to understand the processes to occur on the land grazed by or suitable for grazing by livestock. To avoid a possible negative scenario, it is proposed to use advanced methods of monitoring forage lands – data of Earth’s remote sensing. The monitoring outcomes gathered in a 2000-to-2020 time span are presented herewith. Normalized difference vegetation indices are calculated for each target year. The highest average NDVI values are observed in the spring (March–April) and autumn (September–October) months. The grazing areas with different NDVI values that contribute to different productivity rates of the vegetation cover, were identified: less than 0.2 – greenless, from 0.2 to 0.4 – sparse vegetation, more than 0.4 – dense vegetation. The paper establishes areas of grazing acres varying in vegetation canopy in the semi-desert and desert zones. In 2000, 5.6% (over 0.4) of the total grazing area yielded the most productive value, with the value of NDVI 0.2-0.4 to make up 90.9%. In 2010, there was a trend towards a decrease in the productive area: a zone with more than 0.4 was 166.06 km² or 0.5%, with 0.2-0.4 1,650.28 km² or 4.9%. In 2015, the indicators increased significantly and the area of the productive NDVI value over 0.4 amounted to 83.23%, but in 2020 there was a sharp decrease in the area with live green vegetation to 3.1%.

1. Introduction
The Republic of Kalmykia is located in the southeastern part of the European territory of the Russian Federation, while a significant part of the area is located within the Caspian lowland. The geographical location determines the arid climate of the area, along with higher aridization from west to east and from north to south [1-3]. Due to harsh soil and climatic conditions, the territory lacks moisture. Thus, the amount of atmospheric precipitation per year fluctuates between 210-340 mm, while the amount of evaporation exceeds the annual precipitation rate by 3-4 times, being the reason for which the region is...
considered a zone of risky farming. The soil cover is represented by zonal brown semi-desert soils in combination with alkali soils. These are marginal soils with low natural plant productivity.

The sphere of industrial production is poorly developed in the region, with the main part of the economy to be involved in farming. The land available in the Republic of Kalmykia includes 7,473.1 thousand ha, of which 6,317 thousand ha are agricultural land. Affected by natural and climatic conditions, the largest share of all agricultural land comes from natural rangelands, which is 84.9%. Admittedly, grazing lands account for about 8% of the territory of Russia. The area of arable land as a whole is 832.5 thousand ha in the country, or 13.2% of all agricultural land. This structure of the land available determines the focus of the agrarian sector mainly on livestock production, namely, pasture beef cattle breeding, beef and fine-wool sheep breeding. The major livestock farms are concentrated in the central and eastern areas of the region. The livestock inventory evaluated in the Republic of Kalmykia shows that today the number has decreased to the level of the late 1980s. An actual pasture load in the region on average amounted to 1.19 conventional head of sheep per ha [2-6].

The paper is geared towards an ecological assessment of the status of pastures in the semi-desert and desert zones of the Republic of Kalmykia using remote sensing data.

2. Object of research

Rangeland management in the desert and semi-desert zones was assessed and forecast based on remote sensing data of the Earth, as well as field geobotanical surveys. The source of information for space images was comprised of image databases from Landsat and MODIS satellites in the open access on the geoportal of the US Geological Service.

Figure 1. Geocological assessment of grassland management in the desert and semi-desert areas

The QGIS cross-platform system was used as a geographic information system, together with the Google Earth Engine (GEE) free cloud platform (https://code.earthengine.google.com) that quickly processes large amounts of information using the JavaScript programming language.
The combined territory of the Yashkul, Cherkzemskaly and Yustinsky districts located in the desert and semi-desert zone of the Republic of Kalmykia (Fig. 1) was assessed for rangeland management. The target area houses the major livestock farms of the region, specializing in sheep breeding, which have the greatest contribution to the live grazing vegetation. The total area of the three districts selected for monitoring is about 33,922.7 km².

3. Research and Discussion

Since the mid-90s, the number of livestock has been steadily growing in the republic, which, together with global warming, negatively affected grassland productivity [2,5,7]. To implement measures to prevent and reduce the harmful effects, it is necessary to carry out activities on tracking, analyzing and predicting the development of the situation. Earth remote sensing methods help to determine the level and degree of degradation of study surfaces.

The NDVI that stands for normalized difference vegetation index was used as an indicator of the degree of forage land productivity. It is a quantitative indicator of photosynthetically active biomass calculated as follows:

\[ NDVI = \frac{NIR - RED}{NIR + RED}, \]

where:

- \( NIR \) and \( RED \) stand for the spectral reflectance measurements acquired in the near-infrared and red (visible) regions, respectively.

The NDVI can take on values varies between -1.0 and +1.0, while there is a scale of values, which indicates biomass density at a given point.

The authors used medium-resolution satellite images (Landsat 5, Landsat 8) from the open databases of the US Geological Survey (USGS) – EarthExplorer, for conducting a geocological assessment of rangeland management in the desert and semi-desert zones to determine the NDVI areas with different values. The QGIS geoinformation environment was applied to process images, create vector layers and calculate the area. The Semi-Automatic Classification Plugin installed in the GIS was also used for atmospheric correction [8-11].

The Google Earth Engine (GEE) cloud platform with a MODIS MOD13Q1.006 low-resolution dataset was used to perform the analysis for the entire target period of time and to plot the NDVI changes. It rests on the best reflectance pixel-based images with a spatial resolution of 250 meters generated every 16 days, enabling to neutralize the influence of cloudiness during monitoring. The findings show that the highest average NDVI values are observed in the spring (March-April) and autumn (September-October) months (Fig. 2.). This season-bound productivity is a characteristic feature of the arid zone, resulting from hot dry summers.

Based on long-term data, in spring the NDVI value ranges from 0.4 to 0.45, although in 2001, 2003 and 2020 low values were recorded being 0.28, 0.29, 0.28, respectively. Autumn indices are slightly less than spring ones and vary in September from 0.25 to 0.3. Resulting from heavy autumn rains in 2013 and 2019, the average NDVI exceeded 0.58 and 0.5 units, respectively. Besides, due to the drought in 2020, it hardly ever rained in the autumn, which caused the NDVI to remain at the summer level, around 0.2, which corresponds to dry vegetation.

Based on the results of satellite images processed, the areas of grazing acres with different NDVI values were calculated: less than 0.2 – greenless, from 0.2 to 0.4 – sparse vegetation, more than 0.4 – dense vegetation (Fig. 3) in the time span between 2000 and 2020. In 2000, the vegetation with the most productive value over 0.4 occupied 5.6% of the total area, and sparse vegetation accounted for 30,640 km², which accounted for 90.9% of the total area. In the future, there was a trend towards a decrease in the productive area, as a result of which in 2010 the zone of more than 0.4 amounted to 166.06 km² (0.5%), and less productive in the range of 0.2-0.4 1650.28 km² (4.9%). Subsequently, in 2015, the indices increased significantly and the area of the productive NDVI value of more than 0.4 amounted to 28,077.25 km² (83.23%), but in the subsequent reporting year in 2020 this indicator was no more than 1,056 km² (3.1%).
Figure 2. Average monthly NDVI value according to MODIS data (MOD13Q1.006) for the last 5 years.

Figure 3. Changes in NDVI vegetation canopy in the desert and semi-desert zones of Kalmykia for the period 2000-2020 according to data from Landsat satellites.
4. Conclusions
A series of studies result in some negative trends to be observed in plant communities, as well as an increase in the number of degraded soil areas against the background of unfavorable weather conditions and agricultural impacts induced by the irrational use of grazing land. Space-based means of observing the Earth’s surface are one of the most effective tools of obtaining data for analyzing the state of the vegetation cover of agricultural land. These methods provide prompt information about the ongoing phenomena over large areas, which is a great assistance to researchers in fighting against degradation processes.

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