SHORT-TERM VEGETATION COVER CHANGE ANALYSIS (2020–2025) IN THE LOWER AMU DARYA STATE BIOSPHERE RESERVE USING SENTINEL-2 DATA

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Abstract. This study analyzes the vegetation cover changes in the Lower Amu Darya State Biosphere Reserve during the period 2020–2025 using remote sensing (RS) techniques. Based on NDVI (Normalized Difference Vegetation Index) data, the condition of vegetation, its degradation level, and the spatial dynamics of vegetation cover were determined.

Keywords: Lower Amu Darya State Biosphere Reserve, GIS, Remote Sensing (RS), NDVI, Google Earth Engine (GEE), Tugai forests, Sentinel-2, Ecosystem, Landscape, Field surveys, Ecological monitoring.

Introduction

Under current global climate change conditions, one of the most pressing environmental processes in our region is the ecological transformation occurring in the Aral Sea basin. Among the major challenges is the reduction of forested areas due to drought and other anthropogenic impacts, which in turn have a significant effect on the regional ecosystem balance.

Regular monitoring and assessment of changes in natural ecosystems are among the most essential directions of ecological research. The condition and temporal changes of vegetation cover serve as key indicators in assessing environmental stability and in analyzing the influence of human activities on ecosystems.

Vegetation indices—particularly NDVI—are widely used to assess vegetation density and health conditions. The main objective of this research is to identify the changes in vegetation cover in the Lower Amu Darya State Biosphere Reserve between 2020 and 2025, and to calculate their spatial distribution (in hectares).

The Lower Amu Darya State Biosphere Reserve is located in the lower course of the Amu Darya River, between the Tuyamuyun Reservoir and the Aral Sea, across a wide alluvial plain. The territory borders the Aral Sea to the north, the Ustyurt plateau to the west, the Zangyuz Karakum to the south, and the Kyzylkum desert to the east. It adjoins Gurlan district of Khorezm region and the Beruni and Amu Darya districts of the Republic of Karakalpakstan [1].

The reserve is situated about 90 km from the city of Nukus and 44 km from the center of Beruni district. Its total area covers 68,717.8 hectares, consisting of three zones: the core zone (11,568.3 ha), buffer zone (6,731.4 ha), and transition zone (50,418.1 ha) [1].

Remote sensing and GIS-based studies of forest resources have been conducted by Otokhonov O.D. and Matchanov M.J. (2024) using the Khorezm oasis as a case study. In their work, tugai forests were digitized using GIS technologies, vegetation cover was analyzed through remote sensing, and anthropogenic risk factors were evaluated through spatial analysis [2]. This methodological approach served as the basis for the present research.

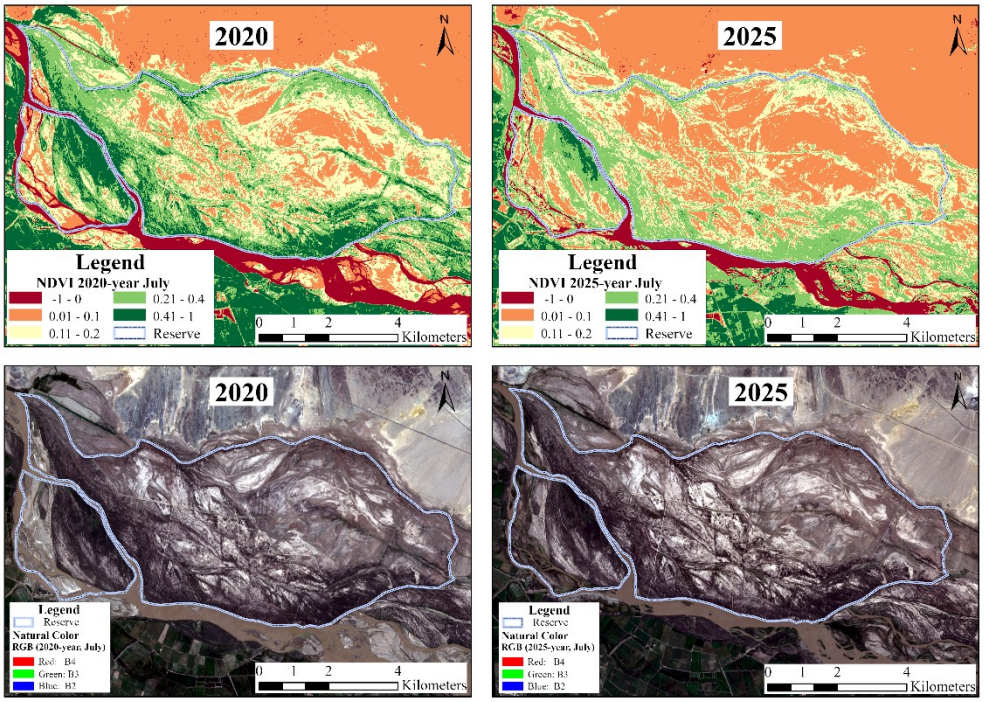
In a study conducted by Reimbayeva J.M. (2024), the ecological condition and ornithofauna of the Lower Amu Darya Biosphere Reserve were analyzed. The author highlighted that the decline in vegetation cover—particularly reed (Phragmites) areas—has led to a decrease in the number of bird and other animal species in the region, thereby affecting the ecological balance of the ecosystem (Reimbayeva, 2024) [3].

Similarly, Reimov M.P. and Pulatov A.S. (2016) analyzed ecosystem services within the reserve using GIS technologies. Their research re-evaluated the zonal structure of the reserve and produced separate maps for five key types of ecosystem services: provisioning, regulating, habitat, cultural, and others. The study emphasized that the tugai forest ecosystems are undergoing degradation due to water scarcity and anthropogenic pressure, and highlighted the necessity of enhanced protection for habitat-related ecosystem services [4].

In the study conducted by Cesaro J.-D., Jolivot A., and Taugourdeau S. (2019), the ecosystems along the Lower Amu Darya riverbanks were mapped through a field mission. The research, carried out within an ecosystem-based land use and conservation project, identified the spatial distribution and condition of tugai forests and other landscape types. The work highlights the practical value of field surveys and mapping methods in assessing landscape elements and provides a valuable basis for ecological monitoring and conservation planning in the region [5].

Methods. The central part of the Lower Amu Darya State Biosphere Reserve was selected as the study area. The boundaries of the study site were digitized based on open-source geospatial data from OpenStreetMap (OSM) and Google Earth Pro platforms [6].

NDVI values were calculated using Sentinel-2 satellite imagery on the Google Earth Engine (GEE) platform [2]. NDVI is used to indicate vegetation health and density, as well as the spatial distribution of soil and water surfaces. Since the highest vegetation activity typically occurs during mid-summer and cloud cover is minimal during this period, the study used Sentinel-2 images from July with less than 10% cloud cover, and a median composite was generated to minimize atmospheric and cloud-related effects.



The satellite images were downloaded and analyzed in ArcGIS Pro. Based on the characteristics of the area, NDVI values were classified into appropriate ranges using the “Reclassify” tool. The reclassified raster images were then converted into vector format (Raster to Polygon) to calculate the area of each class in hectares (Figure 1).

Figure 1. Vegetation cover of the Lower Amu Darya State Biosphere Reserve

Based on these results, thematic maps were designed and a final cartographic representation was created. Additionally, for visual interpretation of the area’s natural condition, Natural Color composites were prepared, allowing for a realistic depiction of the land surface (Figure 1).

The NDVI analysis revealed significant changes in the vegetation cover of the Lower Amu Darya State Biosphere Reserve between 2020 and 2025. These variations indicate potential impacts on the ecosystem structure and landscape dynamics of the area (Figure 2).

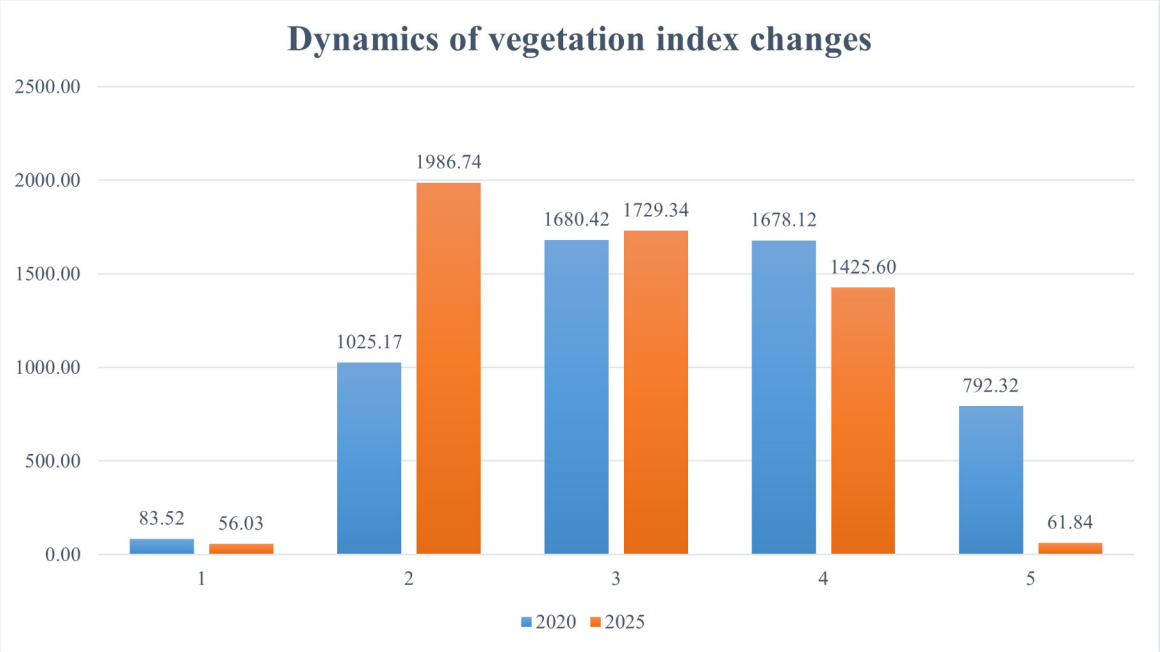


Figure 2. Dynamics of vegetation index changes (hectare)

The following main trends have been identified: significant changes were observed in vegetation condition and NDVI values. Areas with the lowest NDVI values (0.01–0.10) decreased from 83.52 ha in 2020 to 56.03 ha in 2025, indicating a slight reduction in sparsely vegetated or degraded areas.

In contrast, the 0.11–0.20 NDVI range increased from 1025.17 ha to 1986.74 ha, suggesting an expansion of transitional or recovering ecosystems.

For the moderate NDVI range (0.21–0.40), the area increased slightly from 1680.42 ha to 1729.34 ha, indicating a relatively stable vegetation condition.

However, higher NDVI values (0.41–0.60) declined from 1678.12 ha to 1425.60 ha, reflecting degradation in some densely vegetated zones.

Meanwhile, very high NDVI values (0.61–0.80) showed a dramatic decrease from 792.32 ha to 61.84 ha, suggesting a significant loss of dense tugai forests and shrub-covered areas.

Overall, the increase in low and medium NDVI values alongside the decline in high NDVI classes indicates a general trend of vegetation density reduction across the study area.

Conclusions

The conducted research revealed that between 2020 and 2025, significant quantitative and qualitative changes occurred in the vegetation cover of the Lower Amu Darya State Biosphere Reserve. According to the NDVI analysis results, areas with high vegetation values have decreased, while low-value zones have expanded. This indicates ongoing vegetation degradation and disruption of the natural ecological balance.

The main causes of these changes include alterations in the Amu Darya River's flow direction, reduced water levels, and increased soil salinity. These factors have negatively affected the condition of tugai forests and forest ecosystems in general.

Throughout the research process, remote sensing technologies (Sentinel-2) and GIS methods were effectively applied. This approach enabled the identification of vegetation dynamics, calculation of area changes, and cartographic representation of landscape transformations within the study region.

At the same time, it is necessary to continue the research, assess the accuracy of the results, and compare them with other remote sensing and ground-based observation data. Such an approach will help to gain a deeper understanding of vegetation changes and their ecological implications in the Lower Amu Darya region.

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