Vegetation monitoring in the South Aral Sea region by remote sensing and GIS

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Abstract. Vegetation plays an important role in the study of the environment at the local level. Because plants help to understand the negative changes taking place in the region in a timely manner. One of the most effective ways to get reliable and high-quality information about the condition of plants in a short time is remote sensing. The research selected one of the southern Aral Sea regions of Uzbekistan, which is closest to the dried-up part of the Aral Sea. The research examined changes in the condition of water bodies and sparse and dense vegetation over the past 9 years. The research was conducted using ArcGIS software from the family of modern GIS technologies, using data from Landsat 8. Based on the data obtained from these methods, it was found that the water sources and sparse and dense vegetation areas change over months and years. At the same time, depending on the level of vegetation cover, the periods of agricultural pasture use and fodder harvesting were determined. Using these methods, we are able to make the necessary predictions for the use of pastures.

1 Introduction

Every living and non-living object is sustained on the land surface which is directly and indirectly affected by the structure of the land surface [1]. Changes in land cover on the local and regional scales have led to alterations in global biogeochemical cycles, and loss of productive ecosystems and biodiversity [2]. Drought has generally been acknowledged as one of the most devastating meteorological disasters [3]. Desertification can be characterized by water scarcity, reduced agricultural productivity, loss of vegetation cover, and many other such effects [4]. Climate is a major factor in changing vegetation cover [5]. Plants play an important role in the interaction of the biosphere and the atmosphere, in reflecting the effects of climate change on the growth and distribution of plants, in evaluating ecological processes, and in reflecting and describing regional human activities

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[6, 7]. The growth and development of plants depends on the influence of environmental factors. Because of, the growth of plants is affected by seasonal climate changes [8]. Remote Sensing-based Normalized Difference Vegetation Index (NDVI) is widely used in vegetation condition assessment, focusing mainly on determining long-term environmental conditions [9].

Plant growth is often favored by increased temperatures in areas with abundant water resources, but this increase in temperature adversely affects plant growth in arid and semi-arid regions.

NDVI is a useful index in describing the distribution and seasonal changes of vegetation. NDVI is the most widely used and convenient remote sensing dataset for vegetation and land monitoring.

The NDVI, which is produced from satellite data, is frequently used to examine the conditions under which live, green vegetation grows and to show how vegetation dynamics respond to climate change [10]. By measuring the relative growth and health of the crop, remote sensing vegetation indices can be used to measure growth in agricultural variability [11]. NDVI has been shown to have vegetation values spanning from zero to one. NDVI has been shown to be effective in shrubland communities for the detection of vegetation responses related to drought influences as well as monitoring vegetation development [12]. NDVI is obtained using reflect bands, which can indirectly represent the state of vegetative growth and are hence frequently utilized in quantitative research. In addition to being a function of climate, the NDVI’s unpredictability in temporal and spatial distribution leads to sensitive reactions to transient climate fluctuations. NDVI is a remote sensing index used to measure plant health and differentiate green vegetation from non-green vegetation. NDVI helps to determine the condition of the plant in different areas whether it is deteriorated, unchanged or improved.

The shift in NDVI can be interpreted as a reflection of the vegetation's growth conditions because NDVI is sensitive to the productive, biophysical, and biochemical features of the vegetation. A new method was needed to quantify the NDVI values analysis since the spatial variability of vegetation is intricate and pervasive. This made it necessary to learn the variance trend of NDVI in a region. We could qualify the NDVI value and predict the NDVI change trend if we knew the average NDVI value of each station during each of the distinct seasons [13]. Photosynthetically active irradiation of NDVI has been strongly correlated with vegetation biomass, green cover, and leaf area index. Thus, high NDVI values indicate high vegetation activity. Temporal changes of vegetation can be influenced mainly by climatic factors. Therefore, when analysing this situation using NDVI, it is important to consider these factors to isolate NDVI trends related to vegetation dynamics.

On the other side, multi-temporal NDVI gives an additional temporal dimension to reveal the dynamics of the vegetation. Using data from the multi-temporal vegetation index, remote sensing phenology calculates phenological growth stages, encompassing the beginning and conclusion of the season. NDVI is a good indicator for separating vegetation into sparse and dense vegetation. It is an index adapted to study the condition of vegetation cover using satellite imagery [14].

That is why the main aim of the study is to obtain information on the condition of vegetation and water resources, which is one of the main indicators of pastures, and to study their periodic monitoring on the basis of NDVI indices. Based on the indices, it is important to identify areas with sparse, dense vegetation and water resources and monitor their periodic changes, determine the use of pastures in the study areas and the timing of forage collection, and effective use of pastures.

2 Materials and methods

2.1 Study area

The southern Aral Sea region of the Republic of Karakalpakstan was selected as the study area. The Republic of Karakalpakstan is located in the north-western part of the Kyzylkum Desert, the south-eastern part of the Ustyurt Plateau, and the Amudarya delta. The climate is sharply continental, with dry summers and relatively cold winters, with little snowfall. As a result of the study of the vegetation condition of the Republic of Karakalpakstan (September 2020), the area closest to the Aral Sea was selected as a study area. Because most of the negative consequences of the drying up of the Aral Sea are the first to affect the regions closest to the Aral Sea. In addition, plants were considered to be a key indicator in detecting environmental changes. The total area of the study area is 12958.5 km2 and the geographical coordinate between 58˚15'49 "- 60˚29'54" E and 43˚8'3 "- 44˚7'51" **N (**Figure 1**).**

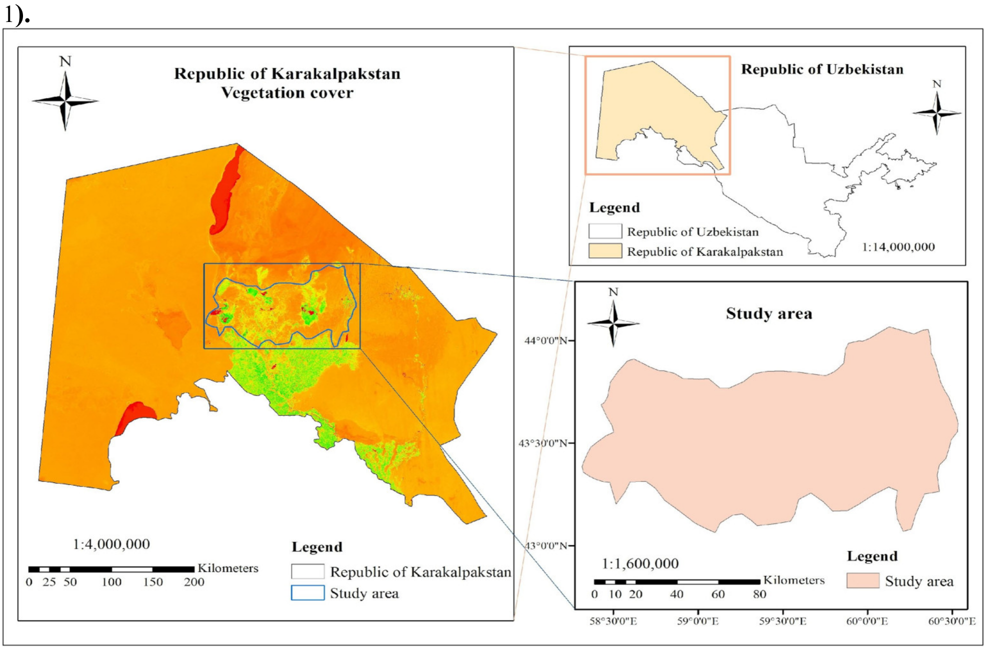

Fig. 1. Study area.

2.2 Research methodology

The spectral properties of the plants enable the study of vegetation using satellite images. Plants do exhibit specific behaviours when it comes to electromagnetic spectrum reflectance. The majority of the energy in the visible range (400–700 nm) is absorbed by leaf pigments. The reflectance decreases as photosynthesis increases. [10].

The amount of chlorophyll, the photosynthetic activity of biomass, and the intake of energy by plants are all closely associated with these parameters.

Hence, NDVI measures plant vigour and greenness and are calculated as follows [15]:

$$NDVI = NIR-R/NIR+R \qquad (1)$$

where: NIR and R represent the reflectance of the near-infrared and the red, respectively. The NDVI is unitless, with values ranging from –1 to +1. Healthy green vegetation normally has the highest positive values [16].

Launched in 2013, the Landsat 8 satellite, which consists of a total of 11 bands, represents NIR 5 band, and Red 4 band (spatial resolution 30 m).

Studies suggest that NDVI values should be considered as a source of water when it is below zero; soil and dry vegetation from zero to 0,3; sparse vegetation from 0,3 to 0,5; and dense vegetation when it is above 0,5 reported.

In this study, Landsat 8 satellite imagery was used to determine the state of vegetation change. And accordingly, research was conducted in the months from June to October to identify changes from 2013 to 2021.

3 Results and discussion

Based on the above data, the vegetation of the study area as of 2021 was studied in the period from March to October. Studies show that vegetation is almost non-existent in March, April, and May. Vegetation peaks from late May to June, and high vegetation is maintained in June, July, and August. From the end of August, the vegetation rate begins to decline, and this condition continues in September and October **(**Figure 2**).**

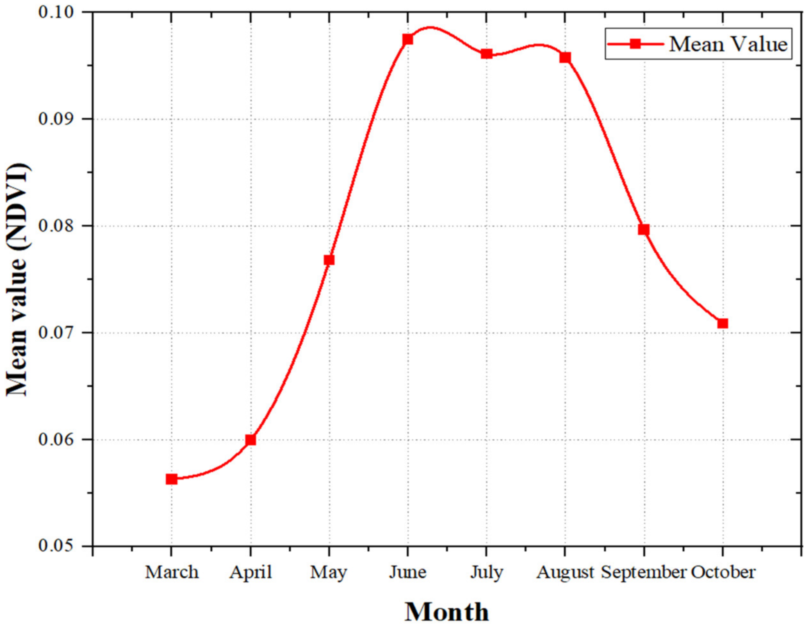

Fig. 2. NDVI mean value as of 2021.

Accordingly, water bodies, sparse vegetation, and dense vegetation conditions were studied in the area. Sparse vegetation begins in April but does not take up much area. It occupied the largest field in June. Although it occupies large areas in July and August, the area continued to decline. The situation continued to decline until October. Dense vegetation began in May. And the highest rates were in June, July, and August. By September, it decreased. Waterbody, on the other hand, begins to decline as the days begin to warm up (Figure 3).

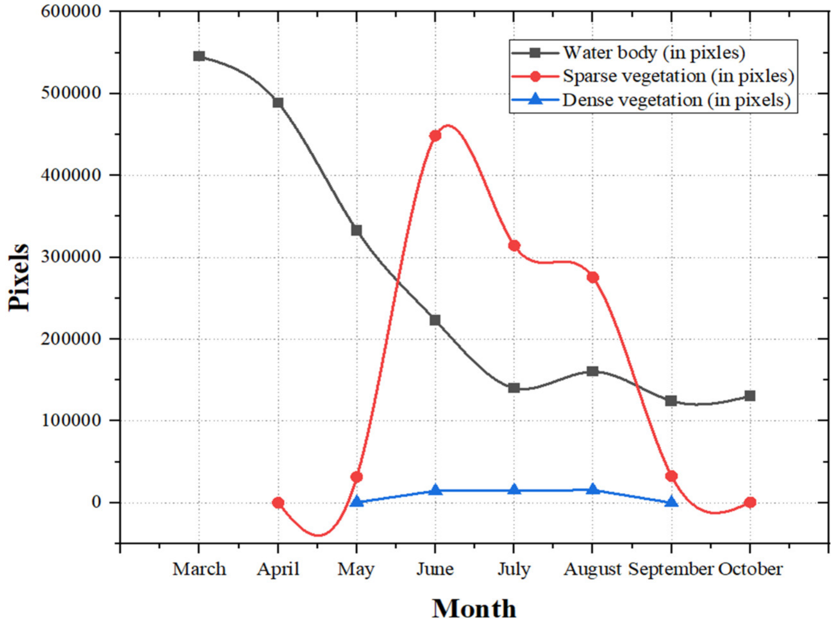

Fig. 3. Changes in water body, sparse and dense vegetation by 2021.

According to the results, the research conducted in the study area is planned to study the changes in the water body, and sparse and dense vegetation conditions during the last nine years from June to October. However, due to the cloud cover in July and August 2013, we were not able to have cloudless images during these months.

NDVI mean value for the last nine years reached its highest level in June in 2013. Respectively, in September and October of this year, the figure was higher than in other years. Between 2016 and 2018, high results were achieved in almost all months. From 2018, NDVI mean value declines have been observed and the lowest figure was in 2021 (Figure 4). Correspondingly, the lowest water coverage in the region is in 2021 (Figure 5).

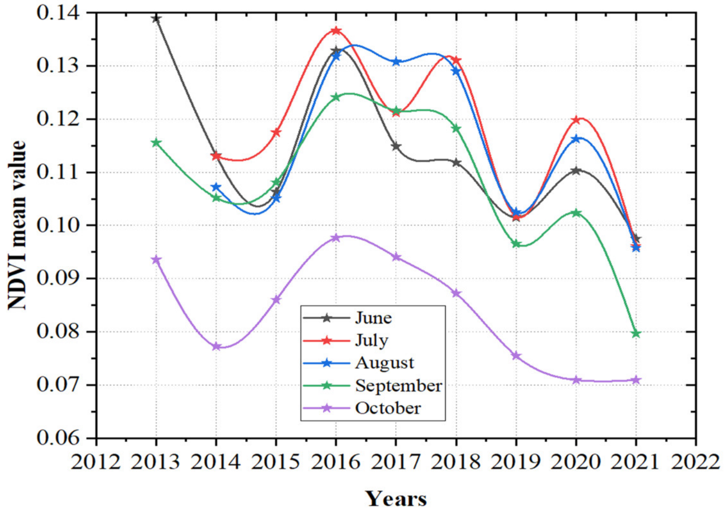

Fig. 4. NDVI mean value in 2013-2021.

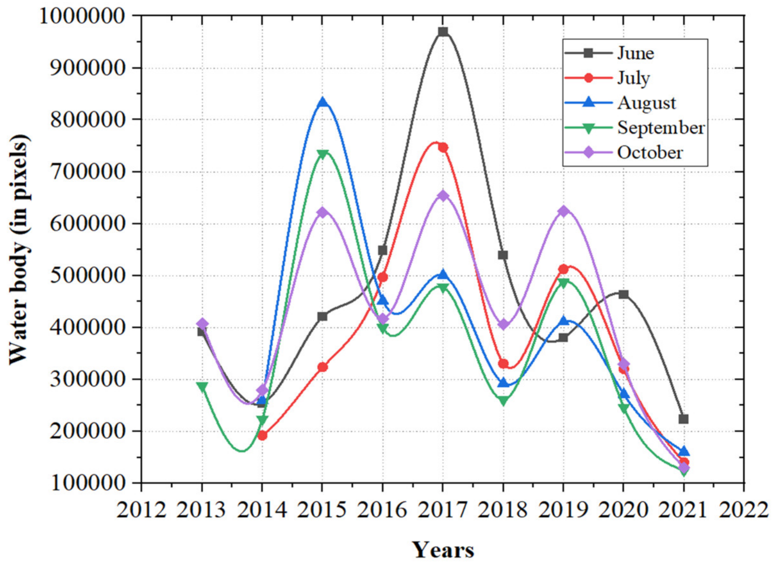

Fig. 5. Changes in the waterbody in 2013-2021.

Data on sparse and dense vegetation show that June 2013 had the largest area in the next 9 years. In 2016, it had relatively high rates in almost all months. Although a decline was observed in 2018-2019, by 2020 the number of indicators has increased. But by 2021, sparse and dense vegetation areas in all months were the lowest in the last nine years (Figure 6 and Figure 7).

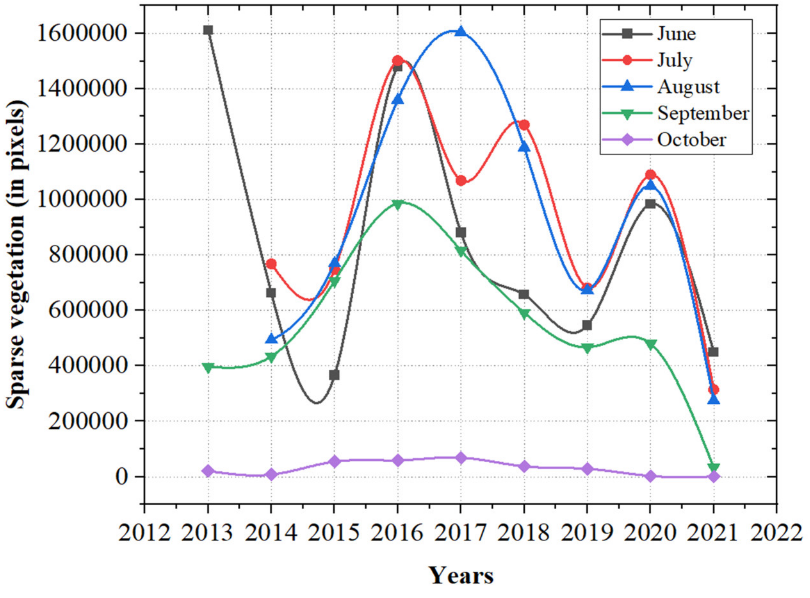

Fig. 6. Changes in sparse vegetation in 2013-2021.

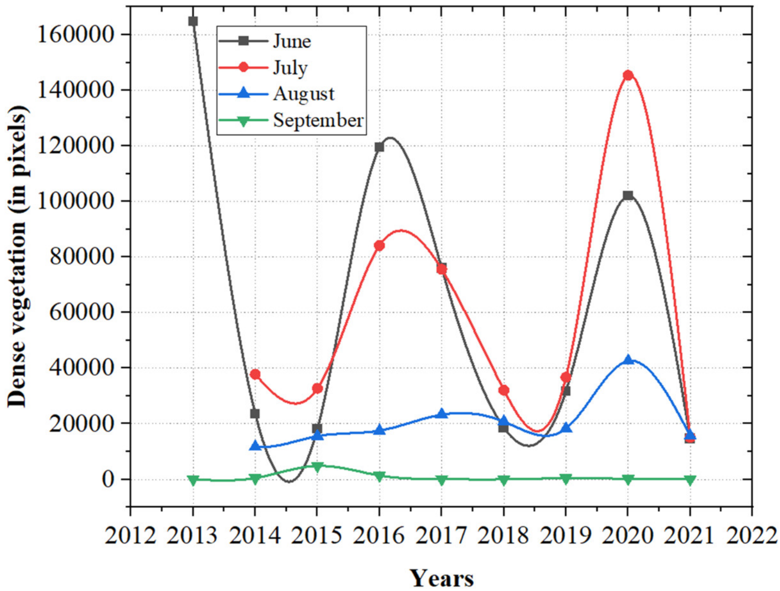

Fig. 7. Changes in Dense vegetation in 2013-2021.

We can also see from the images of the Landsat 8 satellite that the vegetation coverage in the study area was the lowest in 2021 (Figure 8).

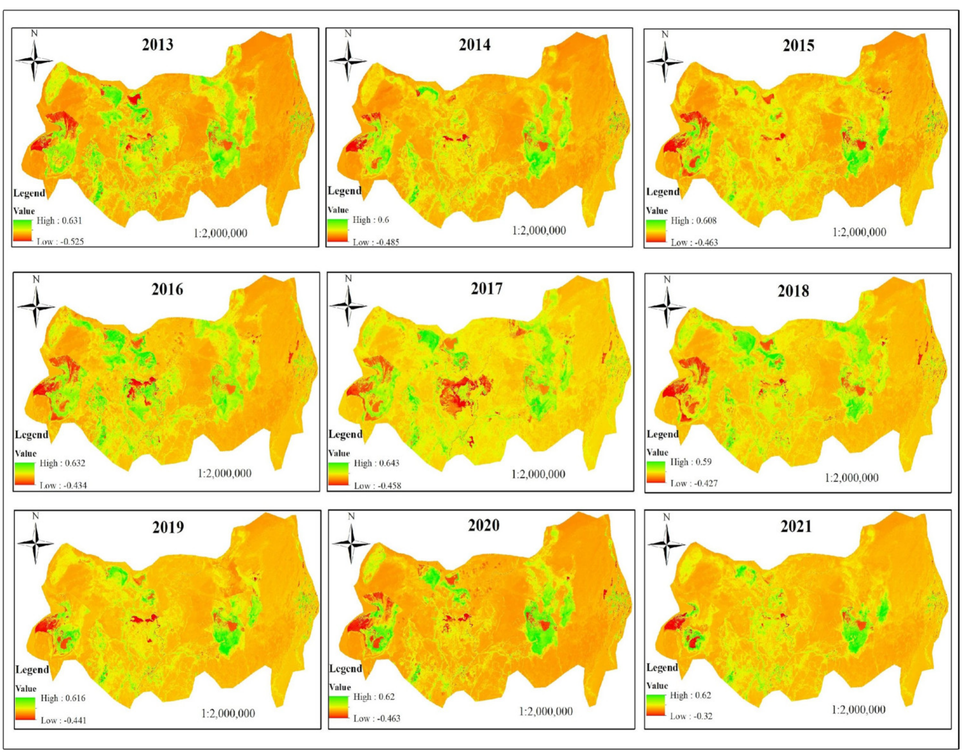

Fig. 8. Vegetation condition of the study area in June 2013-2021.

The above data show that with the change of seasons, the index of vegetation also changes, however, NDVI data and images provided the indicators needed for vegetation monitoring. As a result, it was possible to monitor the vegetation in the study area for a certain period of time [4]. As temperature rises, the area of water bodies decreases and vegetation cover increases, this in turn proved the growth of plants with increasing temperature in areas where water scarcity is not observed [5]. As a result of years of monitoring, showed that the decrease in vegetation area was also related to the decrease in water content in the area. This, in turn, means that changes in vegetation dynamics are related to changes in the environment [10, 17-20]. Results of the use of NDVI indices in determining the area covered by vegetation found that the use of this index in quantitative indicators was effective [13]. NDVI indicators have been used to differentiate between green and non-green plants in the region. This, in turn, has been used to make recommendations on pasture use and forage collection. Considering that values from 0 to 1 indicate vegetation, values below 0 clearly indicate water sources [12]. We can see that the larger the area of the water source before the air temperature starts to rise, the more areas of vegetation will be covered by the decrease in the area of the water source as the air temperature rises. This means that if there is not enough water in the area during the winter, crop yields may decline.

4 Conclusions

The drying up of the Aral Sea is having a negative impact on the areas around the South Aral Sea. Information on the state of water supply and vegetation in the southern part of the Aral Sea in recent years is of great importance for the efficient use of these lands.

Due to the availability of water resources in the study area and the decrease in the area of water sources with the onset of spring and summer, the vegetation that appears on the ground creates favourable conditions for agriculture, especially pastures and fodder production.

It is recommended to use the lands in the study area as pastures from late May to October and to carry out the process of collecting fodder in June and July.

The area of water resources in the region has been declining since 2019 and having the lowest areas in 2021 could lead to a reduction in the amount of land used for forage harvesting. This, in turn, leads to a shortage of fodder in the winter.

As a result of using these methods, we will be able to provide pasture users with information on the condition of pastures from early spring, determine the number of livestock grazed in the regions, and classify the regions according to productivity.

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