Analysis of vegetation changes in the land area of Syrdarya region using GIS technology and remote sensing data

Oykhumor Ruzikulova[1*],

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, National Research University, Tashkent, Uzbekistan

Abstract. This article presents a map of vegetative changes in the Syrdarya region based on remote sensing data. Landsat 8 and Landsat 9 satellite images were used for analysis during the vegetation active period. The study examines the vegetation state of the selected area from 2000 to 2022 and analyzes the changes that have occurred. The Normalized Difference Vegetation Index (NDVI) was calculated using ArcGIS 10.6 software, and the procedure was documented sequentially. The number of color-coded pixels on the map indicating the health and unhealthiness of the crops and the areas they occupy was determined through NDVI analysis. The study revealed a decrease in the vegetation layer in the Syrdarya region, and the reasons for this phenomenon were discussed. The article demonstrates the usefulness of remote sensing in analyzing vegetational changes over time and its potential applications in monitoring the health and productivity of crops in different regions. Overall, this research is valuable for the development of strategies to mitigate the impact of vegetation loss in the Syrdarya region and similar regions facing similar challenges.

1 Introduction

Geographic Information Systems (GIS) have revolutionized the field of earth sciences by providing an automated hardware and software complex that collects, processes, stores, updates, analyzes, and manages topographic, geodetic, land resources, and other cartographic information about objects and events of nature and society[1–3]. GIS is a highly advanced computerized system that can collect and process large amounts of information using various methods and techniques in its database[4,5]. GIS systems are categorized based on the problem they are designed to solve. These categories include Earth information systems, Agricultural, Ecological, Educational, Marine, and other information systems[6,7]. The most common type of GIS is the geographic information system based on a large amount of data. Agriculture is an area that benefits greatly from GIS technology[8–10]. For example, GIS can be used to determine the area of arable land, monitor and analyze changes in vegetation through images taken from space, create spatial schemes or maps, and make predictions based on the collected data[11,12]. GIS is also used to create maps of soil layers, weather patterns, and a range of other purposes. Remote

[*] Corresponding author: oyhumor.ruzikulova@gmail.com

sensing is an important tool for studying terrestrial vegetation. Remote sensing systems are widely used to classify phenomena such as urban growth, land use cover change, vegetation index, and population statistics[13,14]. NDVI is a widely used vegetation index that is calculated by analyzing the visible red light and near-infrared light reflected by plants. Healthy plants absorb most of the visible red light and reflect most of the near-infrared light, while dense vegetation is less reflective in the red band and more reflective in the near-infrared. This allows reliable identification and analysis of vegetation cover separately from other types of natural land cover[15,16]. The minimal temporal resolution of Landsat 8 and Landsat 9 satellite image data allows for the calculation of NDVI to provide operational information about the environment and climatic conditions, and to monitor the dynamics of various parameters at a frequency of up to 1 week[17,18]. The large spatial coverage allows for the observation of areas proportional to the areas of regions and entire countries. Data from high-resolution cameras such as Landsat, IRS, and Aster allow for monitoring the condition of objects the size of a single field or forest stand. The ease of obtaining NDVI is also an advantage, as no additional data or methods are required to calculate the index, and it is not necessary to know the satellite image itself and its parameters[19,20]. The Near Infrared (NIR) layer is particularly useful for analyzing the development of plants and identifying water bodies. NDVI, SAVI, and various other indices can be generated using this layer. These indexes are used in various scientific research and are divided into two layers in all Landsat MSS satellites. In consumption, GIS has become an indispensable tool in earth sciences, and its potential uses are vast. It allows for the processing and analysis of large amounts of data and enables the creation of detailed maps and models of the natural and built environment. Remote sensing, coupled with GIS, allows for the monitoring and analysis of changes in vegetation cover, land use, and other phenomena at a global scale[21]. The future of GIS and remote sensing looks bright, and their continued development and application will undoubtedly lead to further advancements in earth sciences and related fields.

2 Study area

Syrdarya is a region located in the Republic of Uzbekistan that was established on February 16, 1963. It shares borders with the Tashkent region to the east, the Jizzakh region to the west, the Republic of Kazakhstan to the north, and Tajikistan to the south. The region spans an area of 4.28 thousand km2 and has a population of around 900 thousand people. Syrdarya consists of 8 districts named Boyovut, Gulistan, Mirzaabad, Aqoltin, Saykhunabad, Syrdarya, Khavos, and Sardoba. There are 5 cities and 6 towns in the region including Gulistan, Bakht, Syrdaryo, Shirin, and Yangiyer; and the towns are called Boyovut, Dehkanabad, Dostlik, Pakhtaabad, Sayhun, and Khavos. The area was covered with a thick layer of sedimentary rocks during the Mesozoic and Cenozoic periods. Syrdarya is also home to caves such as Shurozak, Mirzarabot, and Sardoba. Some parts of the plain are occupied by lakes, swamps, and salt marshes. In Syrdarya, new canals and ditches were dug, and the desert was cultivated and turned into arable land. Irrigation facilities were built in the plains, and cotton fields, orchards, and vineyards were established. The hills consist of dry lands and pastures. The weather in Syrdarya is changeable and dry, with an average annual temperature of 14°. The average January temperature is -6° in the north and -2° in the south. In winter, the air cools down quickly, and the temperature can drop to -30° (-35° in Gulistan). Sometimes, in the middle of winter, the air suddenly gets colder.

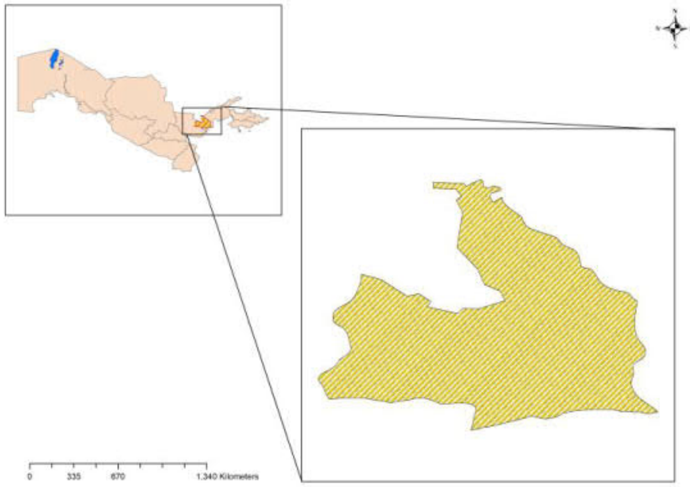

Fig. 1. Study area (Source:www.diva-gis.org/data adapted by ArcGIS)

Frost in late spring and early fall shortens the growing season of the plants. Summer is dry and hot, with an average temperature of 27-29°C in July. The temperature can rise to 32°-45°C, and hot wind (harmsel) dries the soil and adversely affects plant development. The vegetation period in Syrdarya lasts 218 days. The region receives annual precipitation of 180-220 mm, mostly in winter. Due to strong evaporation in summer, underground water fills the soil of the surface areas of Sharof Rashidov, Aqoltin, and Gulistan districts with salt. From November to March, the "Bekabad Wind" reaches speeds of up to 20-25 m/sec, and sometimes up to 40 m/sec in Boyovut district. This wind blowing in spring can sometimes kill budding buds. Isolate plantations have been established in Syrdarya, and the region's soils mainly consist of light-colored weak gray soils with low and medium salinity, consisting of sand and silt soils according to their mechanical structure. Saline and saline-like soils are found

2 Materials and methods

Materials: The study area's spatial image was obtained from the EarthExplorer database and each section was filled in the following sequence:

The research area was selected using a circle and the point was marked with its radius entered;

The spatial image of the selected research area was obtained for the desired year by entering the year in "search from";

Significant months for calculating NDVI and SAVI were selected in the "search month" section, which is mainly in the middle of spring and summer;

After closing the search criteria section, the Data Sets section was accessed;

The Landsat 8-9 OLI/TIRS spatial image of the area selected for the experiment was downloaded from the EarthExplorer database [22].

Data processing: The analysis of vegetation changes in the Syrdarya region required a series of steps to ensure accurate and reliable results. The initial pre-processing steps and operations on satellite images were crucial in improving the quality and accuracy of the remote sensing maps. This included atmospheric and geometric corrections, outlier removal, and mosaicking. By using ArcGIS 10.6 software packages, further analysis was conducted to interpret the results. The "Resample" GIS tool was employed to convert the actual pixel size of the satellite images to 150 meters x 150 meters. This expedited the analyzing process, returned an enhanced visualization, and reduced the size of the remote sensing images, which ensured proper data storage [23]. The Normalized Difference Vegetation Index (NDVI) was then used to detect the canopy cover from the satellite images. This index ranged from -1 to 1 and assessed whether the target being analysed contained photosynthetically active vegetation or not using Equation 1. The NIR (Near InfraRed band of Landsat sensor Landsat 8 OLI) and RED (red band of the Landsat sensor) were crucial in this process. Vegetation cover above 0.3 NDVI was removed from each satellite image to improve the accuracy of the Soil-Adjusted Vegetation Index (SAVI) values. The SAVI values range from -1.5 to 1.5 and enable a sufficient description of the soil-vegetation system and soil type classification. This is essential for estimating the consequences of vegetation change using Equation 2. The use of these methods and tools has resulted in accurate and reliable data on vegetation changes in the Syrdarya region. These steps are essential in remote sensing and provide a foundation for further analysis and interpretation of satellite data[24]. By using these methods, researchers can assess vegetation changes and make informed decisions about land-use change and management. Overall, the use of these tools and techniques is essential in remote sensing and provides valuable insights into changes in the environment, enabling informed decision-making to protect and manage natural resources.

$$NDVI = NIR - RED / NIR + RED \quad \text{Equation 1}$$

$$SAVI = (NIR - RED / NIR + RED) x (1 + L) \quad \text{Equation 2}$$

Where: NIR is the Near InfraRed band of Landsat sensor and L is a soil adjustment factor L = 0.5 .

3 Results and discussion

In order to carry out research in the region of Sirdarya, ArcGIS software was used and NDVI was calculated. Remote sensing facilitates some tasks and serves as a convenient tool for monitoring the changes in permanent vegetation, water area, land area, relief and other factors with the help of photos taken from space. The map created by this ArcGIS program was converted from vector to raster. It helps to calculate the area of the vegetation layer, which is distinguished by colors on the map Fig.2.

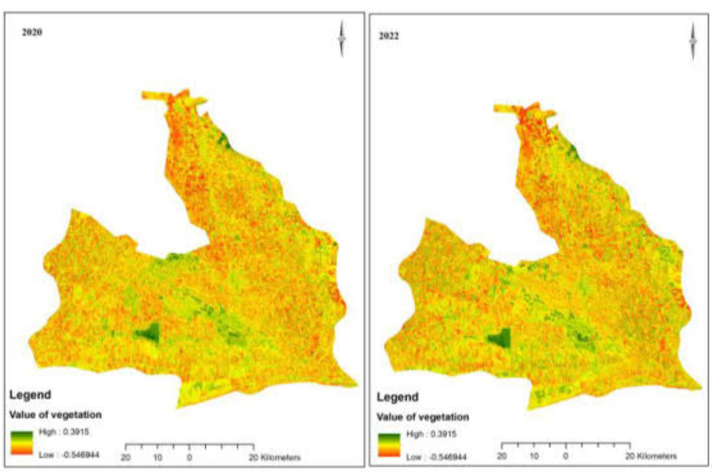

Fig. 2. NDVI analysis map of the study area.

Table 1. Classes on the health and unhealthy plants for 2020-2022

	classes	*number of pixels*	*calculated land area (ha)*	*number of pixels*	*calculated land area (ha)*
		2020	***2022***	***2020***	***2022***
1	Water	197205	23465	17748,45	2111,85
2	Objects or dead plants	498985	37383	44908,65	3364,47
3	Unhealthy plants	3407615	4540952	306685,3	408685,7
4	Average healthy plants	1331361	835226	119822,5	75170,34
5	Healthy plants	1860	0	167,4	0

According to the results, the vegetation indicator in the agricultural land areas of the Syrdarya region has increased in 2022 compared to 2020. This is an encouraging sign, as it suggests that the agricultural sector in the region may be experiencing a positive trend. However, this increase in vegetation may be attributed to a change in the soil properties in these areas. In May 2020, the Sardoba reservoir dam was destroyed, leading to the flooding of large areas and a decrease in soil fertility. As a result, farmers in the region experienced challenges in cultivating crops, as the lack of nutrients in the soil affected the health of plants. Moreover, the reservoir damage also caused a shortage of water for irrigation purposes, which further negatively impacted the land areas in the region. The increase in vegetation indicators in the agricultural land areas of the Syrdarya region in 2022 could suggest that the soil properties have started to recover from the damage caused by the reservoir disaster. This could be due to the natural regeneration of the soil, or through the implementation of soil conservation techniques by farmers in the region. The improvement in the soil properties is crucial for the success of the agricultural sector in the region, as it provides the necessary nutrients for plant growth. The positive trend in the vegetation indicators in the Syrdarya region is a positive sign, but there is still much work to be done to ensure sustainable agricultural practices in the region. The destruction of the Sardoba reservoir dam highlights the vulnerability of the agricultural sector in the region to natural disasters, and the need for effective disaster management strategies to mitigate the impact of such events on the livelihoods of farmers.

Table 2. Plant health classes have been introduced.

pixel spacing	*classes*
<0	Water
0.03-0	Objects or dead plants
0.03-0.3	Unhealthy plants
0.3-0.5	Average healthy plants
0.5>	Healthy plants

One approach to mitigating the impact of natural disasters on the agricultural sector is to invest in water management systems that can provide reliable sources of irrigation water. This could involve the construction of new reservoirs, the implementation of rainwater harvesting techniques, or the installation of efficient irrigation systems that minimize water wastage. Such initiatives can help to reduce the dependence of farmers on rainfall, which can be unpredictable, and increase their resilience to climate change. In addition to investing in water management systems, it is also important to promote sustainable land management practices that can enhance the fertility of the soil and promote long-term productivity (Table 1.2). This could involve the use of organic fertilizers, the adoption of crop rotation techniques, or the implementation of conservation tillage practices that minimize soil erosion. Such initiatives can help to ensure that the soil in the Syrdarya region remains healthy and productive, even in the face of natural disasters or climate change. Overall, the increase in vegetation indicators in the agricultural land areas of the Syrdarya region in 2022 is a promising sign, but it should not be taken as an indication that the agricultural sector in the region is out of the woods. There is still much work to be done to ensure that farmers in the region have access to the resources and technologies they need to promote sustainable agricultural practices and enhance their resilience to natural disasters and climate change. By investing in water management systems and promoting sustainable land management practices, it is possible to create a more vibrant and resilient agricultural sector in the Syrdarya region, one that can provide a reliable source of food and income for the people of the region for years to come.

4 Conclusions

In the Syrdarya region, the number of cultivated areas of healthy plants has decreased from 2000 to 2022 due to various reasons, including changes in weather and ecology, population increase, and use of land for construction of residential areas. The region has also experienced a significant growth in the number of industrial enterprises, which has impacted plant growth. The soil and water quality are critical factors for plant growth, and the NDVI map of the region created using ArcGIS indicates a significant reduction in the area occupied by water. This has led to the use of groundwater for crop irrigation, resulting in reduced soil fertility and increased salinity. These factors have contributed to the decline in healthy plant growth and an increase in unhealthy plant growth.

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