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Application of remote sensing and GIS integration for analysing of water zone: a case study from the Aydarkul-Arnasay-Tuzkon lake system (AATLS), Uzbekistan

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Application of remote sensing and GIS integration for analysing of water zone: a case study from the Aydarkul-Arnasay-Tuzkon lake system (AATLS), Uzbekistan

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Abstract. The lake system of Aydarkul-Arnasay-Tuzkan is located in the Mirzachul lowlands on the territory of Forish district of Jizzakh region, Nurata and Tomdi districts of Navoi region of the Republic of Uzbekistan. Previous researches included scientific studies such as the hydrological regime, condition of groundwater and fishing potential of the lake system, the volume of water flowing into the lake system. However, the impact of changes in water volume on soils around AATLS has not been analyzed using modern GIS technologies and remote sensing. The article compares the methods of distance probing of the state of the water fund lands and analysis using softwares for geographic information systems. According to it, Landsat 4,5,7,8, space velocities from satellite were studied on the basis of the Normalized Difference Water Index (NDWI) and the Modified Normalized Difference Water Index (MNDWI). Visualization of water fund lands showed NDWI 89.5% and MNDWI 93.6%. The return of water as a result of unstable water variability was studied by SI, NDSI, VSSI, SAVI analyzes.

1. Introduction

As a result of global warming around the world, abrupt changes in land cover, in particular the loss of agricultural land, deforestation, depletion of flooded lands have accelerated the melting of permanent glaciers. According to Article 77 of the Land Code of the Republic of Uzbekistan, "Lands of the water fund, which is one of the categories of land resources, mainly include lands occupied by water (rivers, lakes, reservoirs, etc.), hydraulic and other water management facilities. In addition, the land allotted to enterprises, institutions, organizations in the prescribed manner for the needs of water management in the region, allocated along the banks of water zones and other water territories [1-4].

The main tasks of land monitoring are the organization and implementation of a system of monitoring the timely detection of changes in the state of the land fund, their assessment, forecasting of negative processes and the development of recommendations for their prevention and elimination [5]. Many foreign literatures give specific definitions of water fund lands. For instance, "Surface water is rivers, lakes, swamps and oceans. Types of surface water are important freshwater resources for humans and ecosystems" [6].

Water helps maintain biodiversity in coastal or marsh ecosystems by providing habitat for many flora and fauna [7]. Surface water objects are dynamic because they contract, expand, or change their appearance or flow direction due to the influence of various natural and human factors. Changes in water objects have an impact on other natural resources and the human factor, as well as the environment. Changes in the volume of surface water usually have serious consequences such as increase in the volume of surface water can lead to floods and a decrease in them can lead to degradation and salinization. Therefore, it is very important to effectively determine the presence of surface water, to determine its volume, to observe the dynamics of change [8].

Previous studies have researched the hydrological regime of AATLS, changes in wind direction and the flora and fauna of the water objects. The change in the water objects was also analyzed based on remote sensing and GIS integration. However, AATLS as a category of land fund has not been researched through remote sensing and GIS integration. Analysis of soil condition around the lake system has not been studied. The analysis in the Water Fund Land Report and the remote sensing data have not been compared and no measures need to be developed for the area that could result in an environmental hazard [9-13].

The saline and strongly saline areas formed around the lake as a result of AATLS shortening were not separated. Remote sensing data is a convenient tool for making such observations. These days, remote sensing monitoring and mapping are gaining popularity. It is an effective tool in the organization and management of the correct distribution of areas through the use of remote sensing methods in the classification of long-term land use and land cover, integration of data with relevant software [14]. In today's conditions, the shrinking of the water fund lands as a result of global warming may lead to shallowness or even drying [15].

2. Materials and methods

2.1. Study area

The lake system of Aydarkul-Arnasay-Tuzkan, which is the object of research, was originally pasture lands and appeared in 1969 in the territory of Forish district of Jizzakh region, Nurata and Tomdi districts of Navoi region under the influence of anthropogenic factors [9] (Figure 1).

Figure 1. The study area.

2.2. Methods

It is important to monitor the condition of the lake system through periodic observations and to assess and forecast their condition. Therefore, the object of study was researched by the method of spectral analysis of remote sensing data. The obtained spatial data was analyzed in the intersection of years (1990, 2000, 2010 and 2021) according to the Landsat satellite (https://earthexplorer.usgs.gov/). Obtaining geophysical data, their interpretation into software and visualization are based on the following principles.

Normalized Difference Water Index (NDWI) is widely applied in the study of the expansion or contraction of water fund lands [10]. Numerous scientific studies have been conducted to delineate floodplains, identify wetlands and study groundwater to understand their movement [11]. NDWI analysis is an effective way to better understand water availability areas and visualize the boundary between land and water [12]. Data obtained from the Landsat 4,5,7 satellite, green is listed in 2-band (B2) and Landsat 8 in 3-band and near-infrared ray (NIR) in 4-band. This NIR wave is reflected in Landsat 8 in 5-band (B5). Due to the presence of near-infrared ray (NIR) in this formula, the Normalized Difference Water Index (NDWI) also reflects the excess of irrigation water or vegetation-dense areas as water fund lands. As a result of scientific research, Modified Normalized Difference Water Index MNDWI has been proposed [13] (Figure 2).

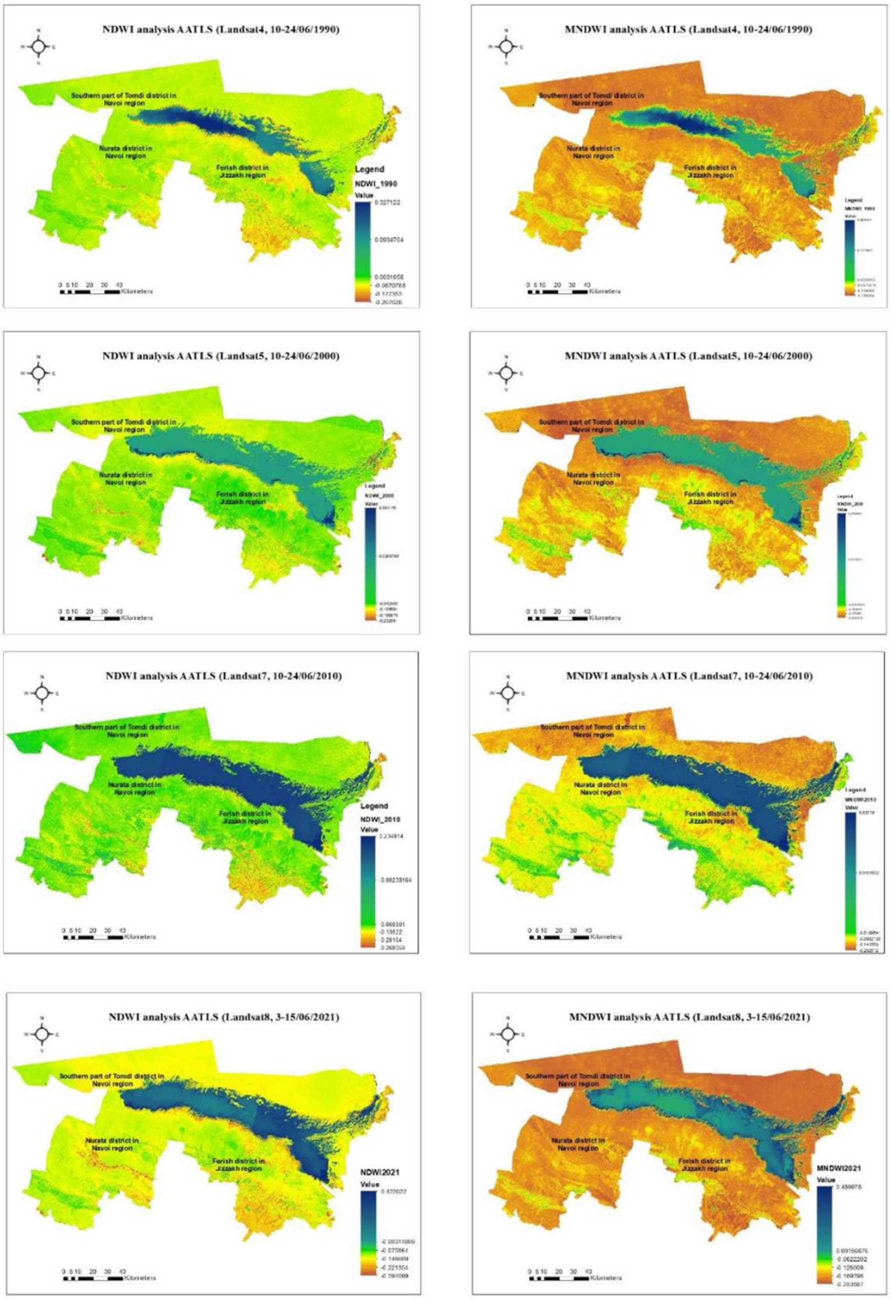

Figure 2. Analysis of AATLS in 1990, 2000, 2010, 2021.

According to Figure 2, the green waves are listed above and are reflected in the 7-band (B7) for short wave of infrared ray (SWIR) Landsat 4, 5, 7, 8. According to the monitoring results, the analysis by NDWI achieved an accuracy of 89.5%, while the study of the region on the basis of MNDWI recorded a result of 93.6%. The use of the MNDWI water fund in the study, monitoring and mapping of lands has been proven to be more effective.

As a result of the analysis, the Normalized Difference Water Index (NDWI) and the Modified Normalized Difference Water Index (MNDWI) for the research object were researched as a result of the studies of space velocities every 10 years from 1990 to the current 2021. According to it, the value of NDWI, MNDWI, was calculated for each corresponding period. The units are the highest, the lowest, and the lower limit of water availability is shown in Figure 3 below. According to it, in 2021, the highest indicator of MNDWI was 0.48, while for NDWI this figure was 0.42. While the lower limit of MNDWI was -0.25, for NDWI this figure was -0.29.

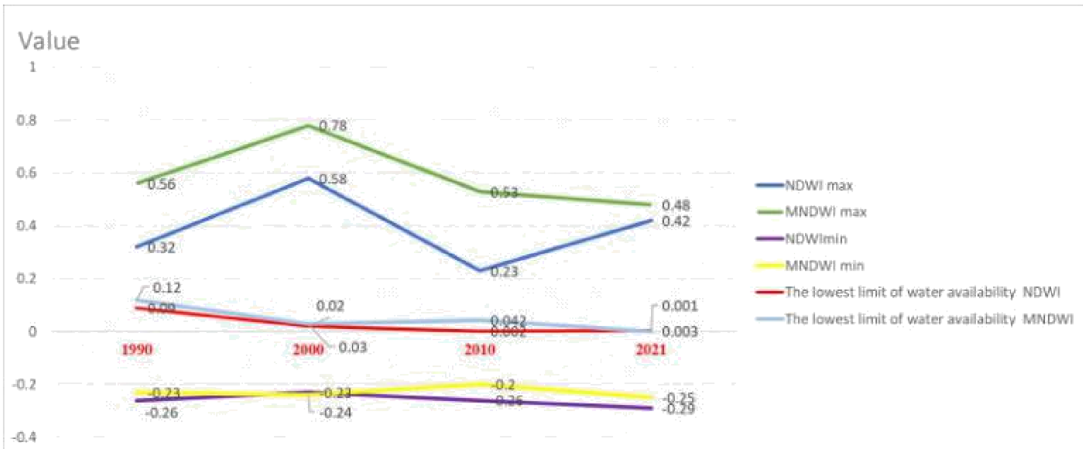

Figure 3. The indicators of NDWI and MNDWI.

3. Results and discussion

In 1990, it was 203,200 hectares, while in 2000 it was 314,000 hectares. In 2010, it was 341,200 hectares. This figure had reached 320,332 hectares by 2021. The reduction of the LSAAT area is having its own negative consequences. For instance, a decrease in water level, an increase in humidity, an increase in precipitation, especially in the return of water in the lake, the formation of saline layers and migration under the influence of wind can lead to a sharp increase in environmental risk. One of the reasons for the reduction in the area of AATLS is characterized by a decrease in the inflow of water from the Chordora Reservoir (Figure 4).

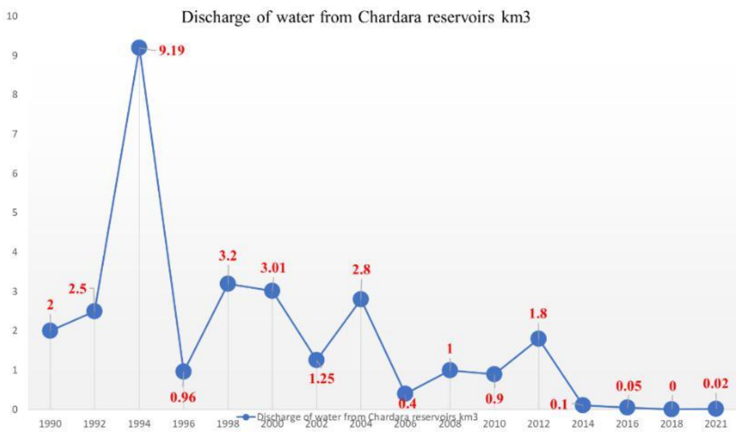

Figure 4. The increase in the volume of LSAAT water depends on the discharge from the Chordora reservoir.

SI, NDSI, VSSI, SAVI analysis were carried out on the basis of Sentinel-2A MSI images were performed in order to analyze the condition of the areas in the return parts of AATLS. Soil salinity is the process of contaminating the soil with water-soluble salts [14]. Determination of soil salinity on the basis of remote sensing is carried out in 3 stages. These are analyzed by remote sensing data, comparing with soil data. And spectral changes are detected by repeating remote sensing analysis. Analysis of spectral changes should be based on images of Sentinel-2A, Sentinel-2B [15]. Comparing the results obtained, the results provided by SI were 86.7% consistent with the data provided by the Department of Soil Valuation of the Cadastre Agency of the Republic of Uzbekistan. The study identified 16 types of soil with dried salt. Of these, low salinity soils were found to be 6 (0.1-0.2%), medium saline soils 3 (0,2-0,4%) and strongly saline soils 7 (0,4-0,8%) (Figure 5).

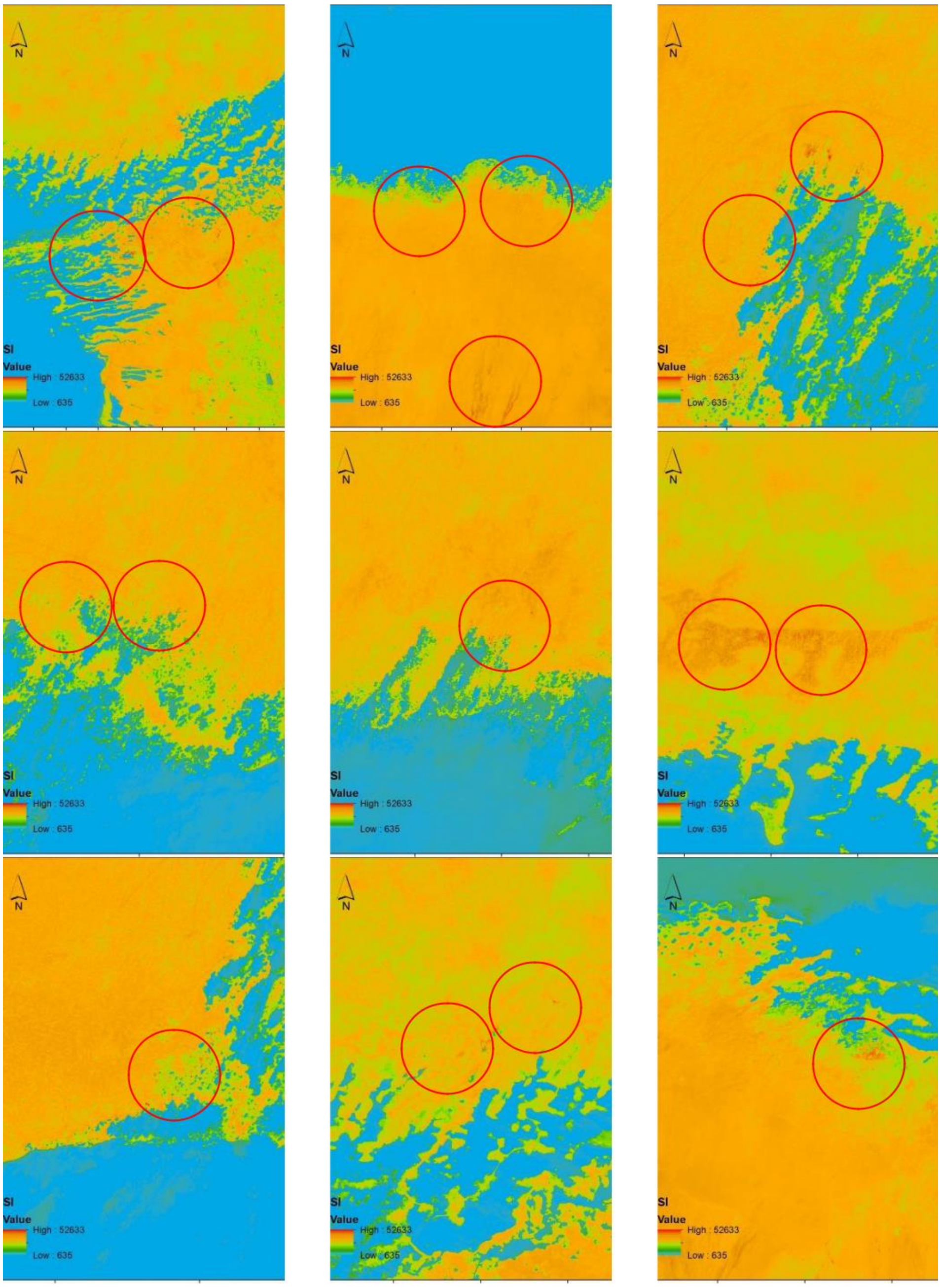

Figure 5. SI analysis of Sentinel 2A and Sentinel 2B.

4. Conclusions

In conclusion, it can be sum up that the monitoring of the lands of the water fund, which is an independent category of the land fund, and the study of their condition is quite important for today. The reason is that the Republic of Uzbekistan is a transboundary water-consuming region with low dry precipitation. In this regard, it is essential to monitor the status of the lake system of Aydar-Arnasay-Tuzkon, which appeared in 1969, by remote sensing and to create maps of water fund lands. The reason is that in 1990 it was 203200 hectares, in 2000 it reached 314000 hectares. This lake system was 341,200 hectares in 2010. From this we can see that the water fund lands have increased by 110,800 hectares compared to 1990. But by 2021, it constituted 320,332 hectares, a reduction of 20,868 hectares in 2010.

As can be seen, the water area is decreasing in the Forish district of Jizzakh region. This warns of new environmental threats, as well as serious concerns about "land ecology". The analysis presented in the article serves to take measures to ensure the implementation of the legislation adopted by our government on stabilization of the lake system of Aydar-Arnasay-Tuzkon. Problems such as the efficient use of land resources and their protection will also be partially resolved.

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