ASSESSING THE EFFECTIVENESS OF REMOTE SENSING AND GEOINFORMATION TECHNOLOGIES IN MONITORING FOREST FUND LANDS

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Annotation.*Traditional methods of land cover monitoring require a long time and involve high costs. In this study, the possibilities of analyzing the soil layer and its composition in arid regions using remote sensing technologies—particularly Landsat and other satellite imagery are examined without field visits by applying indices such as NDVI, VASI, SI, SAVI, and MNDWI.*

Keywords: *monitoring, remote sensing, indices, land resources, NDVI, SAVI, MNDWI, VASI, SI,SAVI and soil.*

Аннотация*. Традиционные методы мониторинга земного покрова требуют значительных временных затрат и являются дорогостоящими. В данном исследовании анализируются возможности изучения почвенного слоя и его состава в засушливых регионах с использованием технологий дистанционного зондирования, в частности на основе данных спутников Landsat и других космических снимков, без проведения полевых работ, с применением таких индексов, как NDVI, VASI, SI, SAVI и MNDWI.*

Ключевые слова: *мониторинг, дистанционное зондирование, индексы, земельные ресурсы, NDVI, SAVI, MNDWI, VASI, SI, SAVI и почва.*

Anotatsiya. *An‘anaviy usulda yer qoplamini monitoring qilish uzoq vcaqtni talab qiladi va kop xarajatli bo‘ladi.Ushbu tadqiqotda qurg‘oqchil hududlarning tuproq qatlami va uning tarkibini masofaviy zondlash texnologiyalari yordamida, xususan* ***Landsat*** *va boshqa* ***sun‘iy yo‘ldosh tasvirlari*** *asosida va NDVI,VASI,SI,SAVI va MNDWI kabi indekslardan foydalanib xonadan chiqmagan holda o‘rganish imkoniyatlari tahlil qilinadi.*

Kalt so‘zlar: *monitoring, masofaviy zondlash, indekslar, yer resurslari, NDVI, SAVI, MNDWI, VASI, SI,SAVI va tuproq.*

Introduction. Land is an important natural resource that meets most human needs and supports a large part of human activity[1]. However, over time, human population growth has intensified changes in land cover and use, placing this natural resource under constant threat[1]. Land monitoring is an important strategic tool for ensuring sustainable food security, rational management of land resources and maintaining ecological balance[5]. Changes in land cover and use are caused by rapid deforestation, increased agricultural production, industrial development, migration, urbanization and population growth. Traditional monitoring methods are often based on visual inspection of the land surface, laboratory analysis and statistical reporting, and these processes are time-consuming, prone to subjective errors and cannot provide complete coverage over large areas. Moreover, monitoring methods are slow, expensive and only suitable for small areas, which makes them unsuitable for modern needs. The most effective method is to monitor land cover using indices using remote sensing.

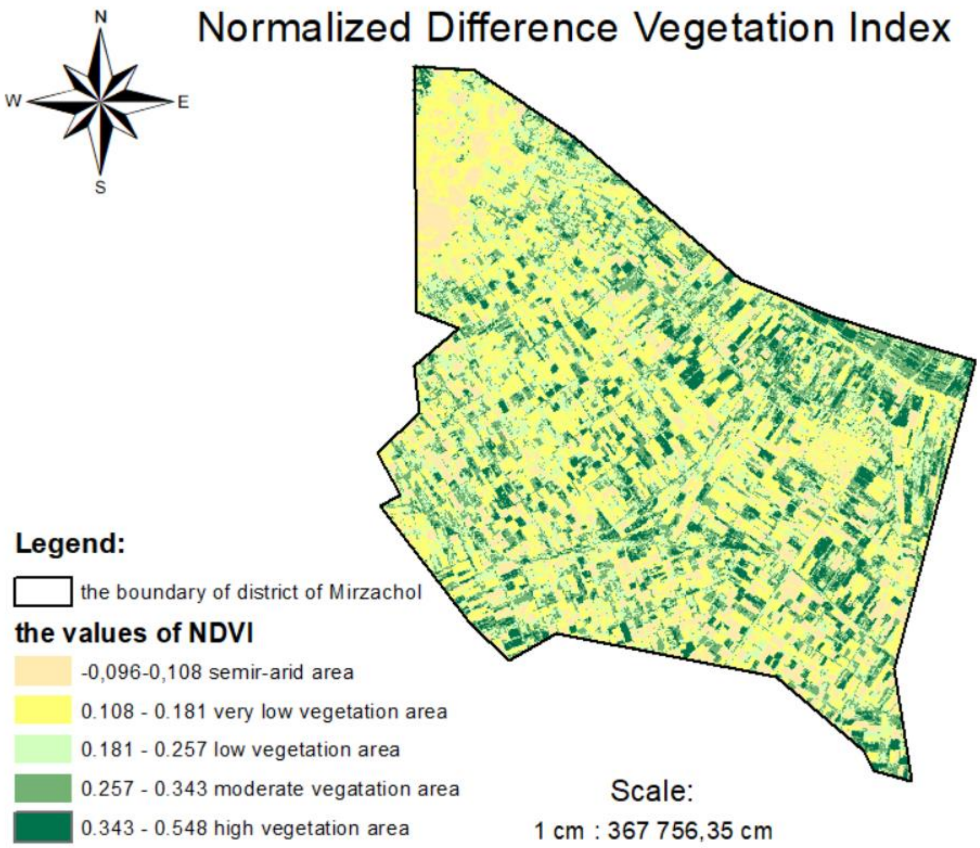
Research area. Mirzachol district - district in Jizzakh region. It was established on January 9, 1967. It borders Kazakhstan to the north, Syrdarya region to the northeast, Dustlik districts of Jizzakh region to the south, and Forish and Arnasay districts of Jizzakh region to the west. The area is 23 thousand km². The relief of Mirzachol district is low-lying. The climate is sharply continental, dry, cold in winter, hot in summer. The average temperature in January is -1.5°, in July 30°; the minimum temperature is -30° (in January), the maximum temperature is 42° (in July). The growing season is 224 days. The average annual precipitation is 240 mm. The soil is light gray and saline loamy soil[2].

Landsat is a satellite system designed for remote sensing of the Earth's surface. It is operated by the United States Space Agency (NASA) and the United States Geological Survey (USGS). The Landsat satellite was launched in 1972 and is one of the world's longest-running Earth observation programs. It is used to monitor land cover and landscapes, and is widely used to analyze water resources and soil conditions. It has also been used to monitor agriculture, forestry, and urban planning, as well as to detect environmental changes and natural disasters. In today's digital world, there are several different indices for monitoring research boundaries. With the help of indices, we can easily monitor the growth period of plants, soil moisture, or degradation. Due to the vegetation and urbanization in our study area, we obtained data using NDVI, VASI, SI, SAVI, and MNDWI indices.

NDVI (Normalized Difference Vegetation Index) – to determine the density and condition of the vegetation cover (Figure 1).

$$NDVI=(NIR+RED)/(NIR-RED)$$

In this study, data from Landsat-9 satellites, band 5 (Near Infrared) and band 4 (Red), were used to calculate the index. NDVI values range from −1 to +1. Negative and near-zero values indicate water surfaces and bare soil, values in the range of 0.2–0.5 indicate underdeveloped vegetation, and values above 0.5 indicate healthy and dense vegetation cover with active photosynthesis. Therefore, the NDVI index is an effective tool for spatial and temporal analysis of vegetation conditions across regions.NDVI (Normalized Difference Vegetation Index). When calculating, it is important to choose the period of maximum greenness (phenological activity) of plants. This period depends on the plant type (navy), climatic conditions and the stage of vegetation. A correctly selected time interval allows you to accurately reflect the real state of plant cover.



1-Figure. *Normalized Difference Vegetation Index (NDVI) analysis of Mirzachul district, Jizzakh region, Republic of Uzbekistan*

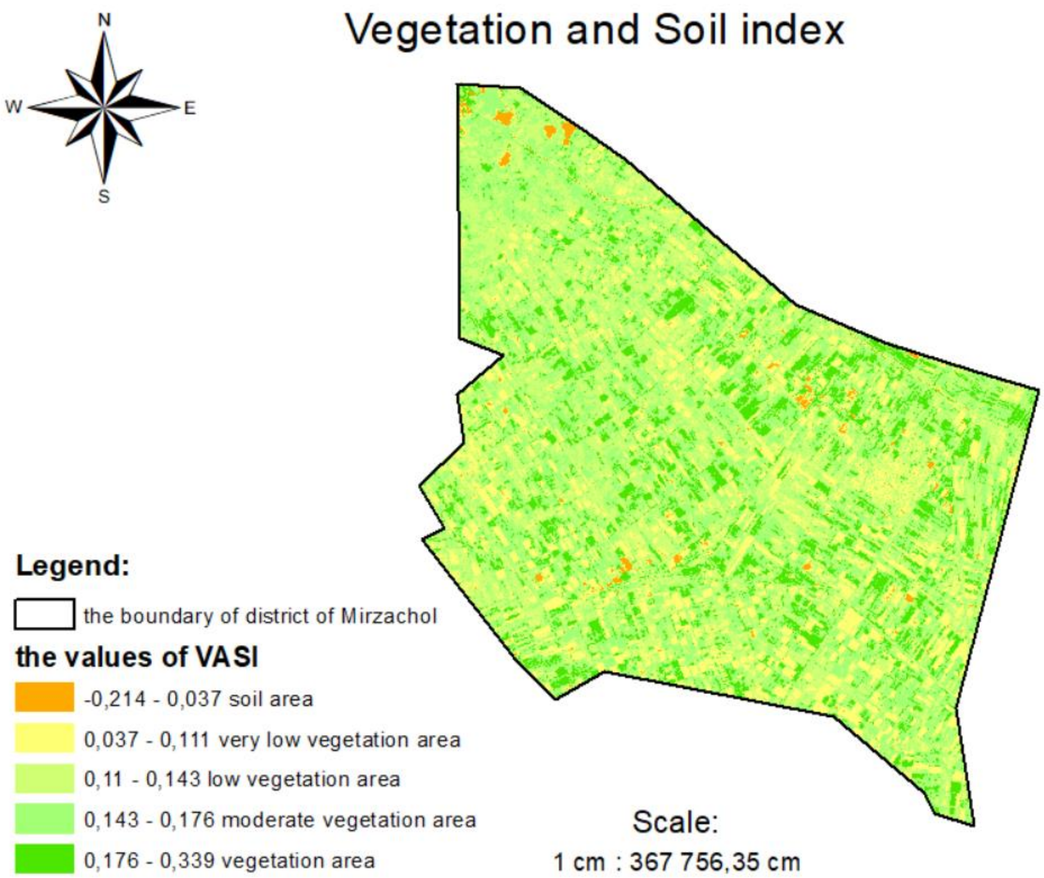
VASI (Vegetation and Soil Index) – To assess the relative plant-soil interaction. It is used to determine the interaction between vegetation density and soil surface in desert or semi-desert areas (Figure 2).

$$VASI=(SWIR-RED)/(SWIR+RED)$$

VASI quyidagi formula asosida hisoblanadi:

$$VASI = (SWIR - RED) / (SWIR + RED).$$

In this study, Landsat-9 satellite data from band 6 (Shortwave Infrared) and band 4 (Red) were used as the SWIR and RED spectral channels, respectively. VASI values range from −1 to +1. Values from −1 to 0 represent areas with mostly open soil and sparse vegetation. This index is an effective indicator for determining the condition of the soil surface and vegetation in arid regions.

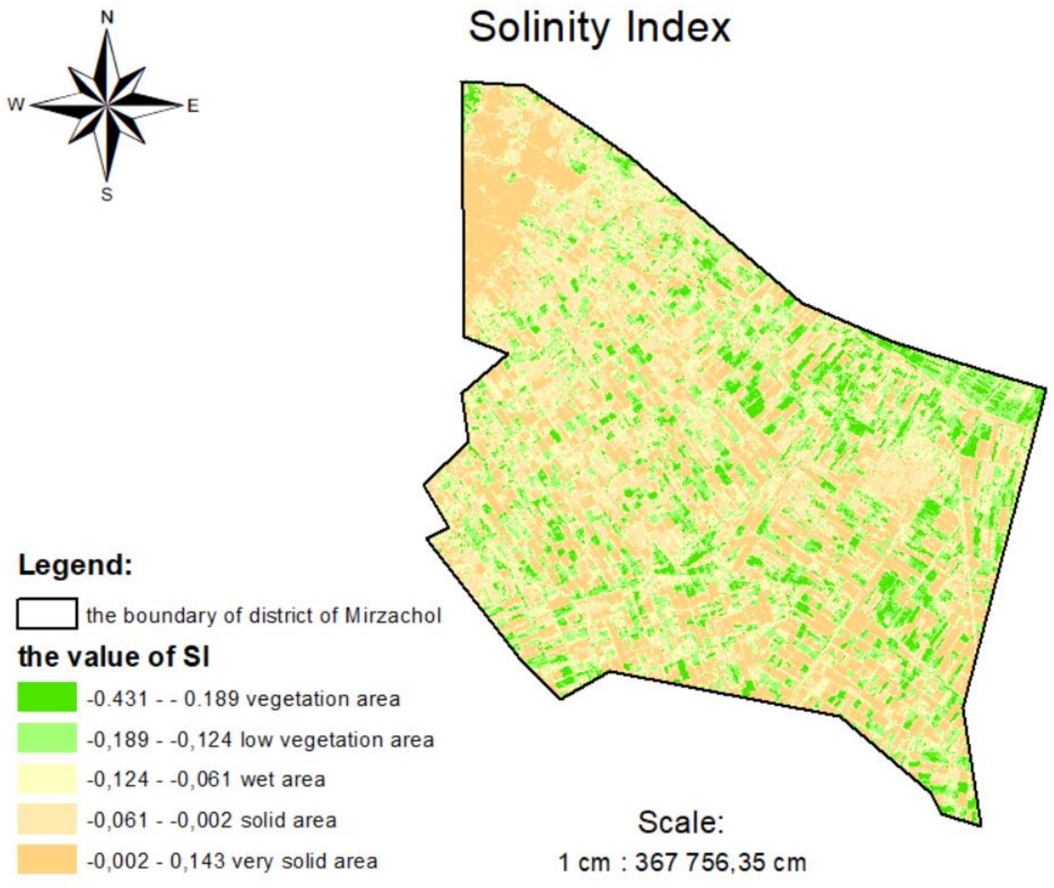


2-Figure. *Vegetation and Soil Index (VASI) analysis of Mirzachul district, Jizzakh region, Republic of Uzbekistan*

SI (Soil Index) – to obtain information about the physical and chemical properties of the soil surface. It is a remote sensing index used to assess the soil surface and soil condition, especially in areas with low vegetation cover (Figure 3).

SI=(SWIR-NIR)/(SWIR+NIR)

In this study, data from Landsat-9 satellite band 6 (Shortwave Infrared) and band 5 (Near Infrared) were used as the SWIR and NIR spectral channels, respectively. SI values vary in the range from −1 to +1. Values in the range of 0.3–0.7 represent dry and bare soil surfaces, and values in the range of 0–0.3 represent relatively moist soil. SI values < 0 are characteristic of vegetation cover or water surfaces. Also, values close to −1 indicate wet soil or areas covered by vegetation, and values close to +1 indicate severely dry and bare soil surfaces. Therefore, the SI index is important for assessing soil conditions in arid regions and identifying land degradation processes.

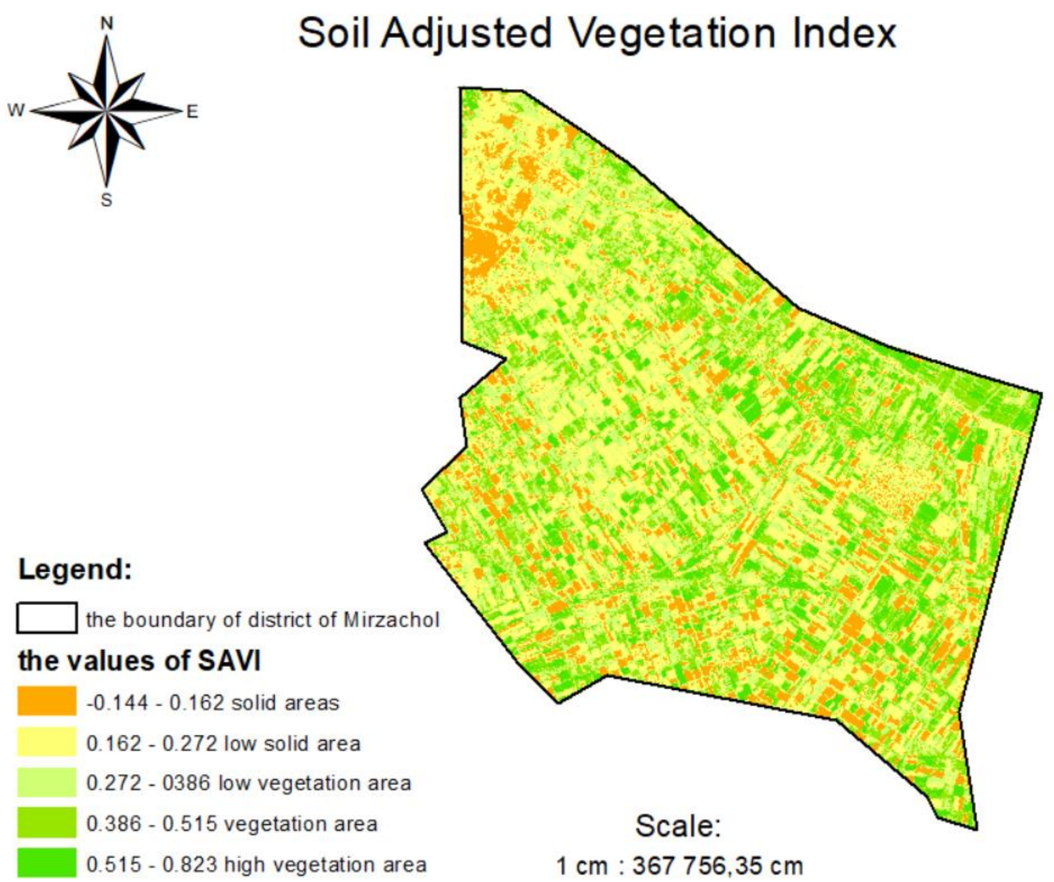


3-Figure. *Soil Index (SI) analysis of Mirzachul district, Jizzakh region, Republic of Uzbekistan.*

SAVI (Soil Adjusted Vegetation Index) – used to more accurately assess vegetation cover in areas with strong soil influence (Figure 4).

$$SAVI=((NIR-RED)*(1+0.5))/(NIR+RED+0.5)$$

In this study, data from Band 5 (Near Infrared) and Band 4 (Red) of Landsat-9 satellite were used as NIR and RED spectral channels, respectively. SAVI values range from −1 to +1. SAVI values < 0 represent water surfaces or clouds, while SAVI < 0.2 represent degraded or dry land. Values in the range of 0.2–0.4 indicate areas with poorly developed vegetation, 0.4–0.6 indicate areas with moderate vegetation cover, and values above 0.5 indicate areas with healthy and dense vegetation. Therefore, the SAVI index allows for a more accurate assessment of vegetation status in arid and semi-arid regions.



4-Figure. *Soil Adjusted Vegetation Index (SAVI) analysis of Mirzachul district, Jizzakh region, Republic of Uzbekistan*

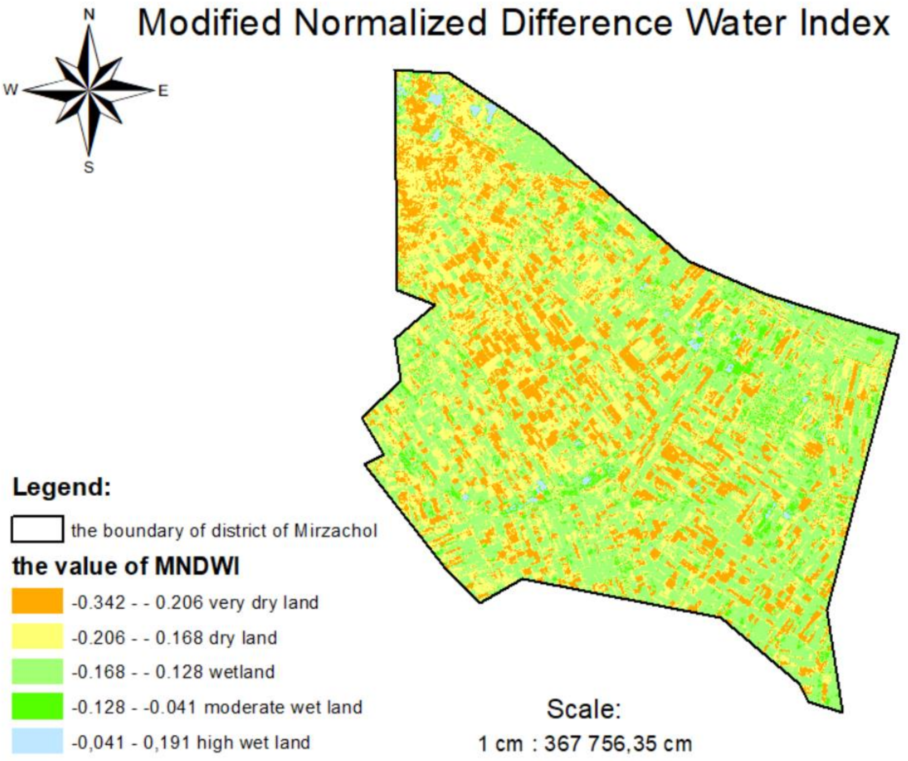
MNDWI (Modified Normalized Difference Water Index) – an index used for water identification and mapping of water surfaces (Figure 5).

$$MNDWI=(GREEN-SWIR)/(GREEN+SWIR)$$

MNDWI quyidagi formula asosida hisoblanadi:

$$MNDWI = (GREEN - SWIR) / (GREEN + SWIR).$$

In this study, data from Landsat-9 satellite band 3 (Green) and band 6 (Shortwave Infrared) were used as the GREEN and SWIR spectral channels, respectively. MNDWI values range from −1 to +1. Values from −1.0 to −0.42 represent soil and dry land surfaces, values from −0.42 to 0.03 represent vegetated areas, and values above 0.03 represent water bodies. Thus, the MNDWI index is a reliable and effective indicator for identifying water surfaces and analyzing their spatial distribution.



5-Figure. *Modified Normalized Difference Water Index (MNDWI) analysis of Mirzachul district, Jizzakh region, Republic of Uzbekistan*

The main reason for using different indices is to achieve the highest accuracy assessment by comparing the results obtained from them. Remote determination of vegetation cover, soil moisture and degradation processes of the area based on these indices using GIS platforms increases the efficiency of research.

Results. The minimum NDVI value in this study was –0.09, and the maximum was 0.34. NDVI index values are widely used to describe the presence and health of vegetation cover. Areas with an NDVI value of –1 to 0 are characterized by surfaces without vegetation cover, i.e. water bodies, concrete or bare ground. According to the results of the study, NDVI values from –0.09 to 0.10 correspond to areas without vegetation cover. NDVI values from 0 to 0.30 indicate the presence of unhealthy vegetation. More specifically, NDVI values in the range of 0.10–0.18, 0.18–0.25 and 0.25–0.34 were evaluated as very sparse or poorly developed vegetation cover. NDVI values between 0.34–0.54 indicate moderately healthy vegetation cover.

The highest VASI value in this study was 0.33, and the lowest was –0.21. In the scientific literature, VASI values are interpreted as follows. Values from –1 to –0.5 indicate very dry or degraded soils, values from –0.5 to –0.2 indicate saline soils, and values from –0.2 to 0 indicate non-vegetated or insufficiently moistened soil surfaces. VASI values from 0 to 0.3 are characterized by the initial stage of the vegetation process. Also, in cases where VASI > 0.3, a clear development of vegetation is observed. Based on these criteria, VASI values from –0.21 to 0.176 in the study area were evaluated as areas with a dominant soil cover. This range was divided into the following sub-intervals: –0.21–0.037; 0.037–0.11; 0.11–0.143 and 0.143–0.176. In these ranges, vegetation cover is almost absent or very poorly developed, and the soil surface dominates. VASI values from 0.176 to 0.33 were interpreted as the initial stage of the vegetation process. These values are characterized by the initial development of plants, a gradual increase in biomass and increased photosynthetic activity.

In this study, the highest SI index value was 0.14, and the lowest value was –0.43. According to the scientific literature, SI index values are interpreted as follows: values from –1 to –0.4 represent wet soils, values from –0.4 to –0.1 represent vegetated areas, and values from –0.1 to 0 represent mixed soil and vegetation surfaces. SI values from 0 to 0.3 are considered dry soils, values from 0.3 to 0.6 are considered saline soils, and cases with SI > 0.6 are considered degraded soils. However, according to the results of this study, all calculated SI index values were summed up in the range from –0.43 to 0.14. As a result, the ability to identify saline and severely degraded soils by the index was limited. This is explained by the fact that the research data correspond to July 9, 2025, because during this period, agricultural crops are actively irrigated and soil moisture is high. High moisture, in turn, prevents the spectral manifestation of signs of degradation and salinity by limiting the shift of the SI index towards positive values.

The highest SAVI value in this study was 0.823, and the lowest was –0.144. According to the scientific literature, SAVI values are interpreted as follows: values from –1 to –0.4 indicate water surfaces or very wet soils, values from –0.4 to –0.1 indicate dry or saline soils, and values from –0.1 to 0 indicate open soil surfaces. SAVI values from 0 to 0.2 indicate sparse vegetation, values from 0.2 to 0.4 indicate moderately developed vegetation, values from 0.4 to 0.6 indicate well-developed vegetation, and cases with SAVI > 0.6 indicate dense vegetation cover. Based on these criteria, SAVI values in the study area were divided into the following classes. Values from –0.144 to 0.162 were considered as areas with soil dominance. Values in the range of 0.162–0.272 were classified as sparse vegetation, values in the range of 0.272–0.386 as average vegetation, values in the range of 0.386–0.515 as good vegetation, and values in the range of 0.515–0.823 as dense vegetation. It is worth noting that since the research data corresponded to July 9, 2025, the superiority of the SAVI index was clearly manifested in areas with strong soil influence during this period. It is precisely due to this feature that the SAVI index allowed for a more accurate assessment of vegetation cover against a background of sparsely covered soil compared to indices such as NDVI. In general, the use of the SAVI index has shown high scientific and practical significance in assessing the density and level of vegetation development, especially in areas with a predominance of irrigated and open soil surfaces.

The highest value of the MNDWI index in this study was 0.19, and the lowest value was –0.34. According to the scientific literature, the values of the MNDWI index are interpreted as follows: values from –1 to –0.5 represent dry desert areas, values from –0.5 to –0.2 represent areas covered by vegetation, and values from –0.2 to 0 represent dry soil surfaces. MNDWI values from 0 to 0.3 indicate the presence of wet soil, and cases where MNDWI > 0.3 indicate the presence of open water bodies. However, according to the results of this study, it was calculated. MNDWI values were concentrated in the range from –0.34 to 0.19. As a result, the ability to clearly distinguish wet soil and open water bodies by the index was limited. In particular, the predominance of negative MNDWI values indicated that the area was strongly influenced by dry surfaces and vegetation. Therefore, in this study, the MNDWI index did not perform as effectively as expected in identifying water bodies. This is explained, on the one hand, by the limited availability of open water areas in the study area, and, on the other hand, by the insufficient spectral coverage of the moisture signal during the selected time interval

Conclusion. In this study, land cover, vegetation status, and soil properties were assessed based on the NDVI, SAVI, VASI, SI, and MNDWI spectral indices. The results showed that the informativeness of the indices directly depends on their physical content as well as the selected time interval. Since the study data corresponded to July 9, 2025, under conditions of strong irrigation processes and high soil moisture, the SI and MNDWI indices gave limited results in identifying soil degradation and open water bodies. On the contrary, the SAVI index, which takes into account the effect of the soil background, allowed for a relatively accurate assessment of vegetation cover during this period, while the NDVI and VASI indices were effective in distinguishing vegetation density and development stages. In general, the study results confirm that choosing the appropriate phenological and seasonal time for each index in remote sensing-based monitoring is of crucial importance, that is, choosing the right time is one of the main factors in the effectiveness of the study.

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