

THE ROLE OF GIS AND REMOTE SENSING TECHNOLOGIES IN PREVENTING SOIL EROSION IN IRRIGATED AREAS

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Annotation:

This article analyzes the scientific basis and practical application of geographic information systems (GIS) and remote sensing (RS) technologies in preventing soil erosion in irrigated lands. Soil erosion is an important factor threatening the stability of agroecosystems, especially strongly manifested in irrigated areas of arid regions. With the help of remote monitoring methods, risk zones are identified by observing changes in vegetation, relief, and salinity at the earth's surface. On GIS platforms, the amount of soil loss is assessed by mathematical calculations using models such as USLE/RUSLE. The article highlights analytical results in real areas based on scientific and practical research conducted in Iran, Morocco, and Uzbekistan. The effectiveness of erosion monitoring and control measures using spectral indices (NDVI, NDSI), UAV images, and AI algorithms is also highlighted. Based on the results, it is proposed to form an integrated monitoring system with contour planting, drip irrigation, terracing, and other measures.

Keywords: soil erosion, irrigated lands, GIS, remote sensing, USLE, RUSLE, NDVI, NDSI, UAV, relief, contour planting, drip irrigation, monitoring, spectral indices, environmental safety.

Intensive artificial irrigation of irrigated lands, especially in arid and semi-arid climates, activates erosion processes by washing away the necessary surface layer from the soil surface. This leads to a decrease in soil fertility, damage to irrigation infrastructure, and the accumulation of sediments in water bodies, which threatens agrarian stability and food security. In these conditions, technological innovations - remote sensing (RS) and geographic information systems (GIS) - have become the main tools for marketing, monitoring, and management models.

Remote sensing technologies, in particular, optical (Landsat, Sentinel), radar (SAR) and UAV-drone platforms, make it possible to determine the state of the soil surface, vegetation cover, and the degree of salinity of irrigated areas in real or near-real time. In a study published in the MDPI publication, it was confirmed that interrill and gully erosion can be mapped with an accuracy of 4 cm using a digital surface model (DSM) created through dense drone images.

This method allows for deep analysis for small areas with maximum accuracy. At the same time, Covering has the ability to determine signs of susceptibility to erosion, such as a decrease in vegetation cover or increased salinity, using multispectral spectral indices obtained from Landsat or Sentinel images for large areas - for example, NDVI, NDSI, TGSI. For example, an analysis of NDVI and NDSI outbreaks in northeastern Iran between 2003-2022 revealed a low erosion risk in 39.7% of areas, a moderate risk in 58.4%, and a severe erosion risk in 1.9% of areas [1,2,3].

Geomatic platforms - GIS - form a deep scaling base based on spectral indices obtained from remote sensing images, relief values (LS based on DEM), soil types, and control measures (C, P factors). Using the formula RUSLE/USLE: $E = R \times K \times LS \times C \times P$, E = annual soil loss (t/ha) is determined. Here, R - precipitation delay coefficient, K - soil sensitivity to erosion, LS - dependence of relief gradient on length, C - vegetation cover factor, P - control measures (for example, contour planting). This model has been adopted as the main instrument in many international and regional studies, for example, in the Moroccan Ikkour Valley, an average annual erosion of 70 t/ha was determined, and analytical correspondence with spectral indices was emphasized. In China, in the upper reaches of the Mingjiang River, cases of $R = 85-588$ MJ mm/ (year), $K = 0.12-0.30$, $LS = 0.03-46$ were studied, and as a result of RUSLE, soil losses of millions of tons were determined.

Technological Scheme for Soil Erosion Prevention in Irrigated Lands Using GIS and RS

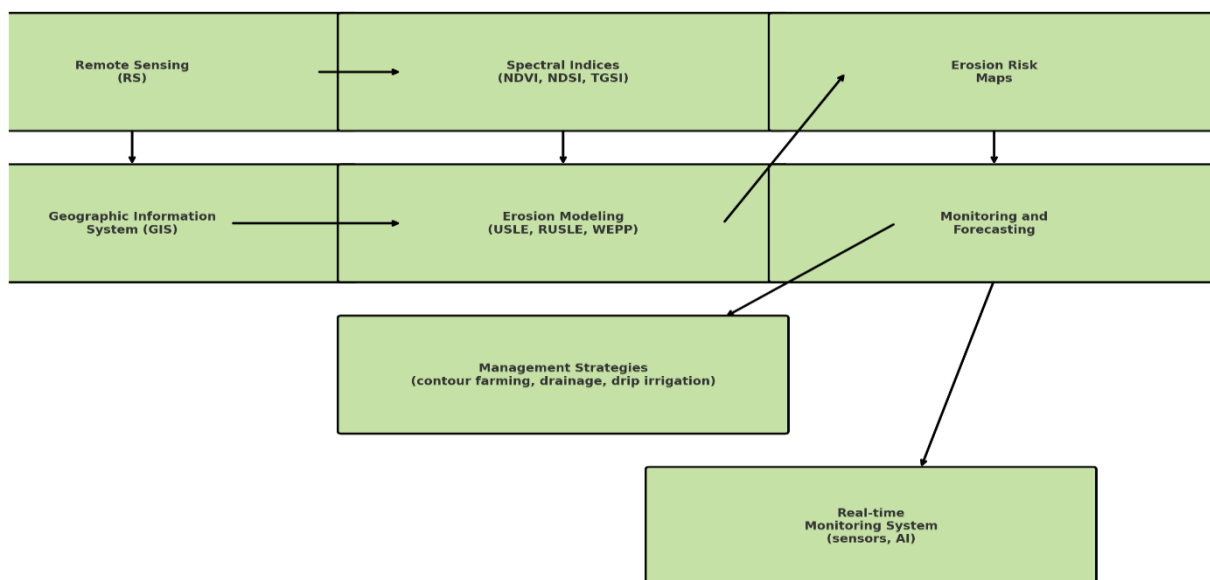


Figure 1. Technological scheme for soil erosion prevention in irrigated lands using GIS and RS

In Uzbekistan, research in the irrigated mountainous regions of Mirzachul, Parkent, and the Bekabad district shows the practical application of the RS and GIS approach. High-precision remote sensing analysis in the Parkent mountainous region showed changes in the land cover and created a model based on GIS for determining degradation and erosion. In Bekabad, the main RUSLE layers - R, K, LS, C, P - were coordinated using Google Earth Engine, and the regions responsible for the annual "light" and "moderate" phenomena were identified [4,5,6]. The main benefit of remote sensing and GIS integration is the ability to monitor in real time, map risk zones, and determine management procedures. Spectral indices consist of monthly Landsat/Sentinel images and weather parameters. In Iran, a sharp change in the NDVI and NDSI signal in 2013 demonstrated the effectiveness of the warning system, linking it to TGSI. This allows for the identification of "early warning" signals, which were previously impossible to detect.

All factors of the RUSLE model previously used in the poem are shown by the GIS in raksta mode: relief gradient through SRTM DEM, precipitation from R CHIRPS or local meteorological statistics, soil type K with OpenLandMap or local soil data; C and P consist of land use spectral analysis and contour irrigation, drip irrigation parameters.

The Mangly Musk Research (WEPP) protocol is also used in integration with RS and GIS, automating the complete process model with parameters. The WEPP enters four main sections - climate, relief, soil, and management - simulating the mechanism of erosion formation and providing the result of sediment transport. This model is more complex than RUSLE, as it organically coordinates hydrological and biometric factors.

Another main trend in the GIS-RS approach is the use of artificial intelligence (ML/DL). Automatic identification of erosion-prone zones by CNN networks and ML models, analyzing RS and terrain data, expresses accuracy at 0.85-0.9 AUC. This will help the authorities and farmers to take prompt action.

Practical measures to prevent erosion in irrigated areas - contour planting, terracing, bundling, vegetation restoration, optimization of drainage networks and drip irrigation systems - are planned and monitored based on RS-GIS. For example, in fields with contour sowing, it was shown that erosion decreases by 30-50% due to changes in C and P factors through spectral indices. These measures are determined based on real zonal maps [7,8,9].

The main limitations are: high cost and non-renewal of high-resolution RS images; Lack of geodata related to factor P; Interpretation of AI models and the need for large defined datasets; There are problems such as the unnatural continuity of the RS interplatform data format.

In the future, the following areas will be developed: integrated real-time monitoring (RS + soil moisture sensor + AI); Expansion of local 3D geodata with UAV; cooperation between farmers and khokimiyats through national and regional RS-GIS platforms; construction of warning

systems with mobile applications; Automation of AI-based gully identification; introduction of an additional concept of land degradation neutrality (for example, the integration of these indicators is highlighted in the MDPI 2023 study in Uzbekistan).

In the prevention of soil erosion for irrigated lands, GIS and remote sensing technologies are the main tools for monitoring, modeling, risk forecasting, management, and planning of measures. Such systems can also be formed in Uzbekistan through RUSLE, spectral indices, UAV drones, AI integration, and real-time monitoring systems. In the example of regional analyses (Bekabad, Parkent, Mirzachul), these approaches have already been implemented. In the future, it is expected that these systems will strengthen environmental sustainability and the efficiency of agricultural resources [10-14].

Conclusion

The problem of soil erosion on irrigated lands is one of the most pressing ecological and agrarian problems for Uzbekistan and other arid regions. The loss of the fertile soil layer negatively affects crop yields, limits the efficient use of water resources, and disrupts the overall sustainability of the environment. In preventing this problem, modern technologies, in particular geographic information systems (GIS) and remote sensing (RS), serve as an important scientific and practical tool.

With the help of RS, vegetation, relief, and salinity are analyzed using multispectral images, and zones of risk of soil erosion are identified. GIS platforms, on the other hand, allow mapping, evaluating, and planning management measures based on data modeling (USLE/RUSLE, WEPP). Degradation of vegetation cover is clearly determined by spectral indices (NDVI, NDSI, TGSI), and forms of gully and interrill erosion are clearly determined by UAV (drone) images.

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