METHODS FOR CREATING MAPS OF THE SOILS OF THE DRY ARAL SEA BASIN USING THE QGIS PROGRAM

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ARTICLE INFO

Received: 01st May 2026
Accepted: 04th May 2026
Online: 06th May 2026

KEYWORDS

Dried Aral Sea bed, soil mapping, GIS, GIS technologies, remote sensing, Landsat, Sentinel, salinization, soil degradation, environmental monitoring

ABSTRACT

This study examines methods of cartographic analysis of the dried-up soils of the Aral Sea bed using the QGIS program. The work utilizes modern GIS technologies, including remote sensing data (Landsat, Sentinel satellite imagery) and soil classification methods based on the QGIS platform. During the research, the soil layer, salinity level, granulometric composition, and degradation processes of the area are assessed based on spatial analysis. As a result, the ecological changes occurring on the dried seabed, the current state of soil resources, and their territorial distribution are depicted on precise cartographic maps. This approach has important scientific and practical significance in conducting regional environmental monitoring, rational use of land resources, and development of reclamation measures.

The scientific study of the soils of the dried-up Aral Sea bed and their mapping using modern geoinformation technologies is one of the most pressing environmental problems of our time. As a result of the sharp expansion of irrigated agriculture in the second half of the 20th century, the main flow of the Amu Darya and Syr Darya rivers was directed towards agricultural needs. Consequently, the Aral Sea's water balance was disrupted, and its level decreased year by year. According to historical sources, if in the 1960s the area of the sea was about 68,000 km^2, by the beginning of the 21st century this figure has decreased several times. As a result, over 50,000 km^2 of the dried seabed has formed, and this area is currently developing as a new anthropogenic landscape this figure has decreased several times **(see**

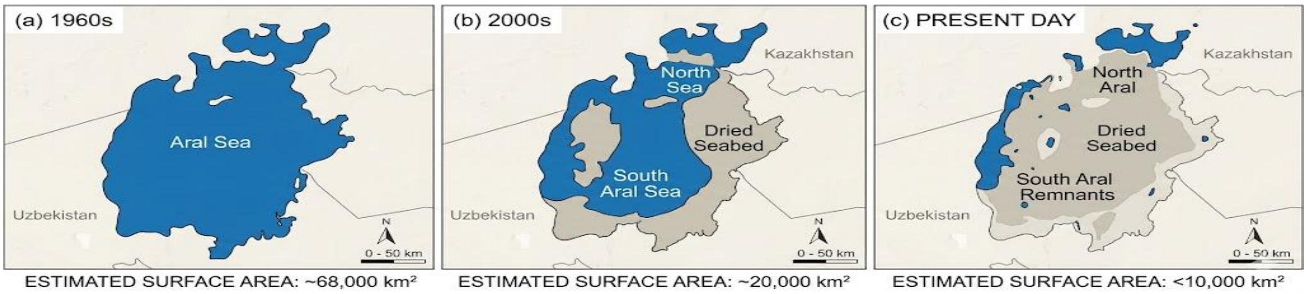


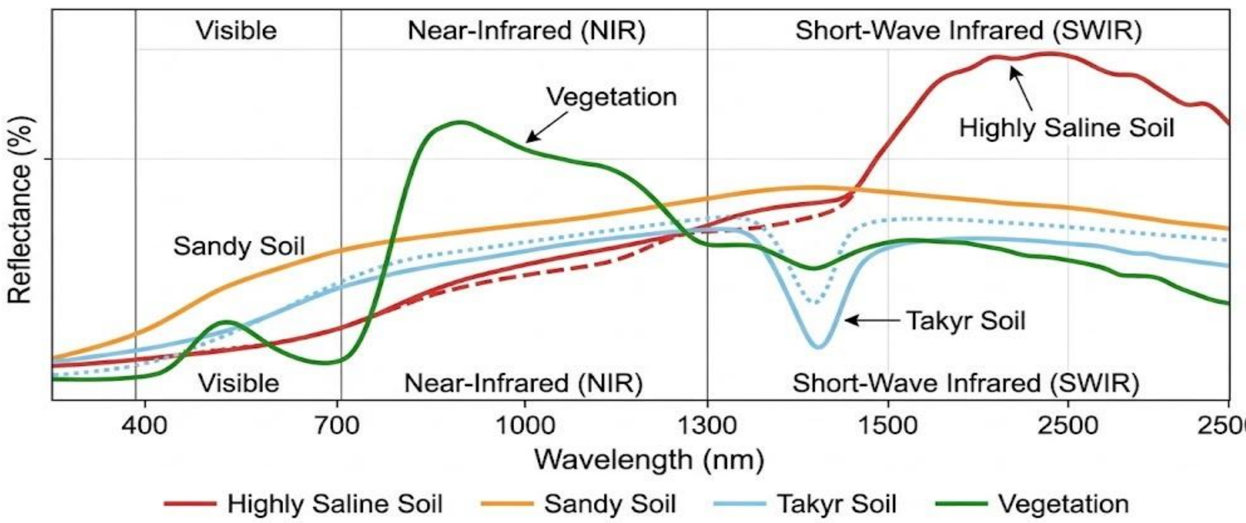
Figure 1).

Figure 1. Temporal dynamics of the Aral Sea shrinkage (1960s – Present Day)

Soils formed in arid regions are distinguished by their complex physicochemical properties. According to scientific research, including fundamental works in the field of soil science and ecology, saline, sandy, and takyr soils are widespread here. A high concentration of soluble salts is observed in the soil, and the degree of salinization in some places reaches 15–20%. Under these conditions, natural vegetation is very scarce, and biological productivity has sharply decreased. At the same time, wind erosion is strongly developed in the region, with an average of 75–100 million tons of dust and salt particles being released into the atmosphere annually. These aerosol flows reach not only nearby areas but also regions thousands of kilometers away, negatively impacting ecological stability.

Geoinformation systems, in particular, the QGIS program, are widely used for in-depth analysis and assessment of these problems. This program is an open-source platform, through which it is possible to collect, process, analyze, and visualize data from various spheres. The use of the QGIS program in scientific research is justified by its high effectiveness in determining soil cover, the degree of salinity, land degradation, and landscape changes. Especially when integrated with remote sensing data, this program creates wide opportunities.

Remote sensing technologies are one of the main sources of information for studying the dried seabed of the Aral Sea. Images obtained through the Landsat and Sentinel satellite systems have high spatial and temporal accuracy, allowing for dynamic observation of changes in the region. While Landsat images typically have a 30-meter resolution, Sentinel-2 data has a 10-meter resolution, allowing for the detection of even minor regional differences. Based on this data, various spectral indices are calculated. For example, the NDVI (Normalized Difference Vegetation Index) is widely used to assess the state of vegetation, while the SI



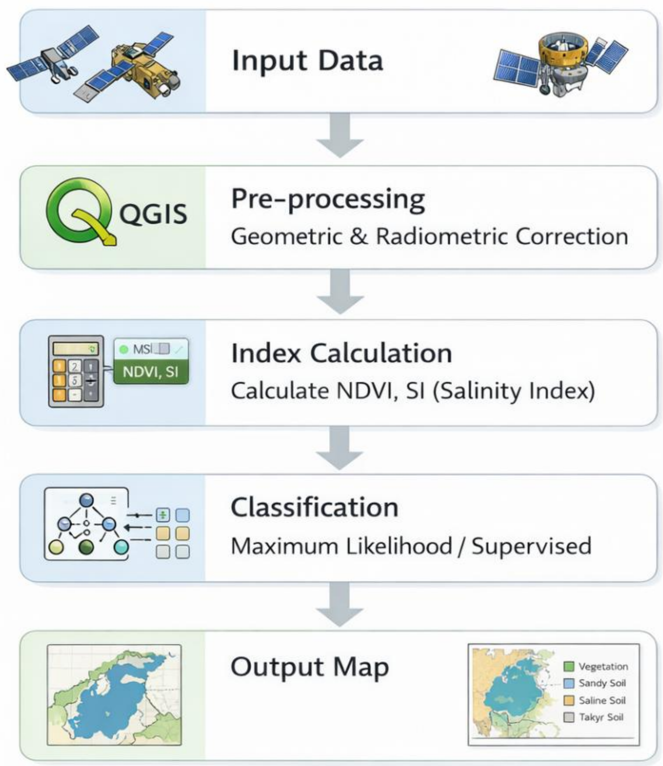
(Salinity Index) is used to determine the degree of soil salinity. In the scientific literature, it is noted that the accuracy of these indices reaches 80–90% to determine the degree of soil salinity **(Figure 2).**

Figure 2. Comparison of soil spectral reflectance across different classification types

In the QGIS program, the soil mapping process consists of several stages. First, remote sensing data is downloaded and processed; geometric and radiometric corrections are made. In the next stage, the images are classified. Supervised and unsupervised methods are used in the classification process. In supervised classification, soil types are determined based on a pre-selected training area, while in unsupervised classification, algorithms automatically group the image. One of the most commonly used methods is the Maximum Likelihood algorithm, which is based on the theory of statistical probability. In the QGIS program, the soil mapping process consists of several stages **(illustrated in Figure 3)**.

Figure 3. Methodological workflow for soil mapping in the QGIS environment

As a result of the analyses, several main soil zones were identified on the dried seabed. According to statistical data, 60–70% of the territory is occupied by highly saline soils. Sandy soils account for 20–25%, while takyr and clay soils are found in the remaining areas. These soils are highly degraded, and their melioration status is extremely poor. Therefore, the



possibilities for agricultural development in the region are limited, but in some places, it is possible to use flexible agricultural technologies.

Reclamation work is being carried out in the area to reduce environmental problems. In particular, large-scale projects are being implemented to reduce wind erosion by planting saxaul, kandym, and other desert plants. It is noted in scientific sources that in recent years, work has been carried out on the afforestation of millions of hectares. This contributes to a significant reduction in dust and salt migration.

Studying the dried-up soils of the Aral Sea bed using the QGIS program requires a comprehensive scientific approach. The integration of GIS and remote sensing technologies allows for accurate assessment of the region's ecological situation, effective management of soil resources, and forecasting future changes. This approach is not only of scientific importance but also of practical importance, contributing to ensuring ecological stability in the region and the rational use of natural resources

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