Study of soil salinity in agricultural land using Remote Sensing data in Amudarya district, Uzbekistan

Eshbolta Qobulov[1*], *Halima* Botirova[2], *Nurullo* Tursunov[1], *Shohida* Jumayeva[1] and *Kamoliddin* Kabulov[2]

[1]Termiz university of economics and service, Termiz city, Uzbekistan
[2] “Tashkent Institute of Irrigation and Agricultural Mechanization Engineers” National Research University, Tashkent, Uzbekistan

Abstract. One of the primary concerns in agricultural regions is the presence of soil salinity, which is especially prominent in the Amudarya district of Uzbekistan. This investigation aims to evaluate the salinity of the local soil utilizing data acquired through remote sensing. By integrating remote sensing data with modeling methodologies, this study offers a comprehensive understanding of the patterns of soil salinity. The outcomes of the study demonstrate the effectiveness of this approach, with a 72% accuracy in interpolation and a Kappa value of 81%. The study underscores the critical importance of amalgamating modeling techniques and remote sensing data to monitor local changes in soil salinity and assess the potential impact of climate change on soil salinity levels. These findings are of utmost significance in facilitating the planning of water resources and agricultural management, ultimately supporting the sustainable utilization of farmland in the region.

1 Introduction

Across the globe in arid areas, salinization of the soil is a major problem for agriculture, especially in Central Asian countries where irrigation is frequent. Because of soil salinization, the Amudarya district of Uzbekistan faces serious challenges to both its agricultural output and water resources [1]. This issue develops when the number of soluble salts in the soil is more than what plants can withstand, which lowers soil fertility, increases water consumption, and reduces agricultural yields [2]. Soil salinity in the Amudarya district is made worse by high rates of evaporation, inefficient irrigation management, and poor drainage. The principal crop in this important agricultural region of Uzbekistan is cotton, and increasing soil salt levels over time have presented significant issues. Soil salinity has an impact on crop production, but it also affects the water quality, biodiversity in the area, and the ecosystem as a whole. It has been demonstrated that remote sensing technology is a useful tool for measuring and tracking soil salinity [3–5]. It enables data collection across wide regions, giving researchers insights into the dynamics and spatial distribution of soil salinity.

[*] Corresponding author: e.kobulov@mail.ru

This data can support the creation of focused management plans, better irrigation techniques, and increased agricultural sustainability in the Amudarya district [6–8]. The salinity of Uzbekistan's soil has been measured in the past using a variety of techniques, such as geostatistical monitoring combined with recurrent electromagnetic induction (EMI) surveys. These studies highlight how crucial it is to combine field measurements and data from remote sensing to increase evaluation accuracy. Additionally, studies have looked at how agricultural productivity is affected by salinity in the soil, emphasizing the necessity for efficient management techniques [9–11]. The objective of this research is to enhance comprehension of soil salinity in the Amudarya district by the integration of remote sensing data, field measurements, and geostatistical analysis. The results will aid in the formulation of methods to lessen the negative effects of soil salinity on the region's water supplies and agricultural output [12,13].

2 Materials and methods

2.1 Study area

The study area is situated in the Amudarya district, located in the western part of Uzbekistan. This region is characterized by its proximity to the Amu Darya River and plays a crucial role in the country's agricultural and hydrological systems. The area's unique geographical and environmental features make it an important focus for research, particularly in the context of water management and infrastructure development. The study area is located in the coordinates 39,225ºN to 64,684ºE the area is 1 020 km^2 (Figure 1). According to reports of "The Ministry of Agriculture of the Republic of Uzbekistan, 86 % of lands are affected by different salinity degrees in Amudarya district [14,15].

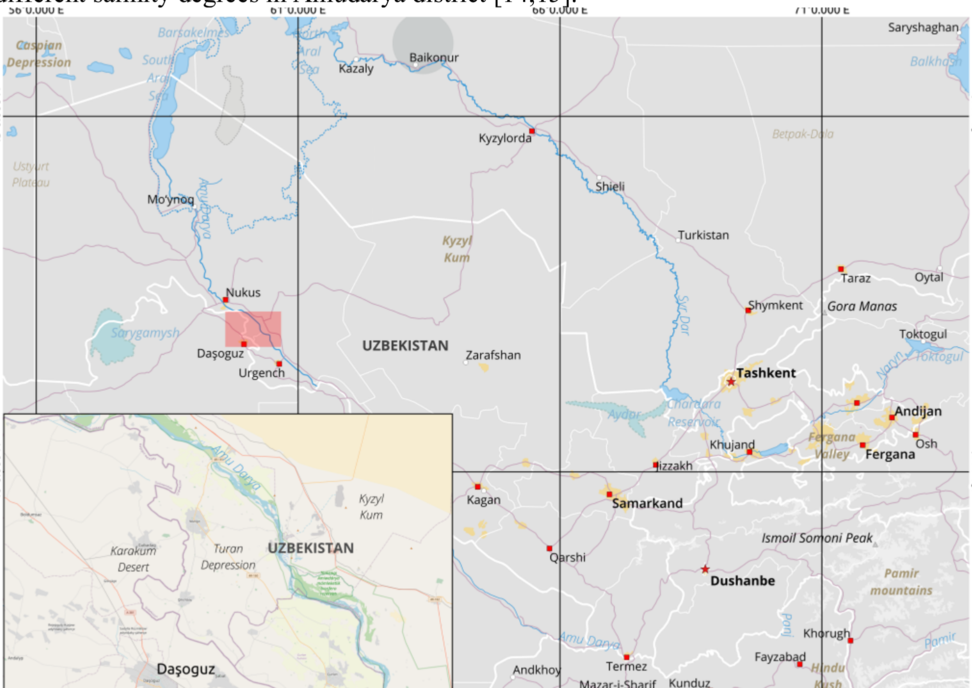

Fig. 1. Study area (source: www.osm.com modified by QGIS).

2.2 Materials

The satellite photos of the research region (Path 154, Row 32) were downloaded from open sources (earthexplorer.usgs.gov) at intervals of five years starting in 2003 and ending in 2023. Landsat 5,8,9 OLI, an Earth observation satellite, has been utilized as a source of satellite pictures (salinity level of arable land increases following vegetative phase in the second part of October and beginning of November). Every sixteen days, the satellite uses high-spectral sensors to take pictures of the entire planet. According to the U.S. Geological Survey (2023), each pixel in the image represents a 30 x 30 meter ground view due to the photos' 30 meter spatial resolution [16,17].

2.3 Methods.

Soil salinity can be found and measured using remote sensing methods such as the Normalized Difference Salinity Index (NDSI). It is based on comparing two distinct spectral bands' reflectance values and computing the normalized difference. The following equations is used to calculate the NDSI (1):

$$NDSI\,\frac{\rho NIR-\rho SWIR}{\rho NIR+\rho SWIR} \quad (1)$$

In the near-infrared (NIR) band, ρNIR represents the reflectance value, typically 0.8-0.9 µm, while ρSWIR represents the reflectance value in the short-wave infrared (SWIR) band, often 1.2-1.3 µm. The purpose of the Normalized Difference Salinity Index (NDSI) is to highlight the impact of salinity on soil reflectance. Saline soils, which contain minerals like gypsum and halite, tend to exhibit higher reflectance in the near-infrared (NIR) range, while non-saline soils typically show lower NIR reflectance. The difference between NIR and shortwave infrared (SWIR) reflectance is more pronounced in saline soils because the SWIR band is less affected by salinity. NDSI values, which range from -1 to +1, provide an indicator of soil salinity levels : values closer to +1 signify high salinity, while those near -1 indicate low salinity (table1). NDSI can be used to create thematic maps that visualize soil salinity, making it a valuable tool for monitoring salinity changes over time and identifying areas with elevated salinity. Numerous studies have successfully applied NDSI to map and track soil salinity using satellite remote sensing data, including from Landsat 5 TM and Landsat 8 and 9 OLI [18–20].

Table 1. NDSI range on soil salinity classes.

NDSI range	Soil salinity level
0.15-0.25	Very high salinization
0.26-0.40	High salinization
0.41-0.55	Medium salinization
0.56-0.70	Low salinization
0.71-1.00	Very low salinization

Due to the automated correction functionalities of the Landsat 5 Thematic Mapper (TM) and Landsat 8 and 9 (OLI) sensors during remote imaging, there is no requirement for atmospheric and radiometric corrections in the present study. In order to comprehend the disparities in spectral reflectance among soil samples exhibiting different levels of salinity, it was imperative to graphically represent their spectral reflectance. This endeavor will facilitate the formulation of a soil salinity index that is specifically customized for desert soils.[21].

 https://doi.org/10.1051/e3sconf/202459001011

3 Results and discussion

Identify temporal changes: By comparing the salinity levels in many photos taken at various times, the NDSI can be used to identify changes in soil salinity over time. Track salinity trends: Researchers can determine trends in salt levels by examining the NDSI values over time. This information can be helpful in understanding how different factors, such as land use changes, irrigation techniques, and climate change, affect soil salinity. Finding high salinity change areas can be helpful for managing water resources and reducing the detrimental effects of salinity on agricultural output. The NDSI can be used to find high salinity change areas.

All things considered, the NDSI is a useful instrument for tracking changes in soil salinity over time. Its application can aid in the development of practical management strategies for managing soil salinity and reducing its detrimental effects on water resources and agricultural production. Based on the analysis conducted, it is evident that the salinity levels in the region were relatively low in 2003. However, by 2008, there was a noticeable increase in areas characterized by high salinity. Subsequently, in 2013 and 2018, an upward trend in salinity levels on agricultural land can be observed. Furthermore, in the past five years, there has been a resurgence in the prevalence of high salinity in the region (Figure 2).

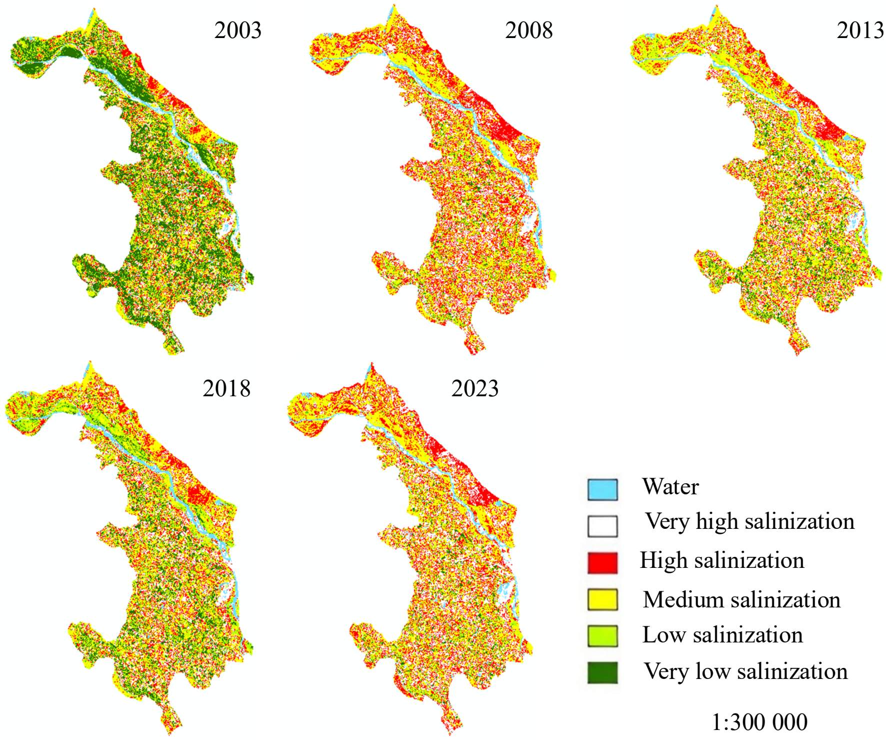

Fig. 2. NDSI analysis (2003 to 2023).

The NDSI analysis's findings demonstrate that the area study's soil analysis conducted with the use of remote sensing technology is represented in the statistics and has practical applications. In the context of remotely sensed data soil mapping, the term accuracy usually refers to the degree of "correctness" of classification. A high level of accuracy should be provided by a map that is produced by a remote sensing categorization procedure. The degree to which a map produced using a remote sensing classification procedure matches actual field data is referred to as classification accuracy.

4 Conclusions

Soil sampling is an expensive, time-consuming, and labor-intensive process. Typically, one soil specialist and two workers will sample the soil 15–20 times a day. As a result, satellite sensors enable the free and accurate measurement of 80% of soil salinization, as demonstrated by our work, and satellite remotely sensed images are currently accessible via the Internet. As a result, mapping soil salinity with GIS and RS is much more affordable and has a greater level of spatial precision. According to our findings, nearly all arable land areas are at risk from various salt levels. Agriculture and our economy will suffer as long as appropriate and timely action is not taken in this area.

References

1. S. Rakhmonov, U. Umurzakov, K. Rakhmonov, I. Bozarov, and O. Karamatov, E3S Web of Conferences **227**, 01002 (2021)
2. A. Inamov, S. Safayev, and S. Mukhammadayubova, E3S Web of Conferences **258**, 03013 (2021)
3. L. A. Gafurova, G. T. Djalilova, O. X. Ergasheva, and K. D. Abdukarimova, Journal of Critical Reviews **7**, 283 (2020)
4. M. M. Bermoy, V. O. Cacayan, J. C. Carido, A. G. Apdohan, and A. O. Cacayan, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives **48**, 81 (2023)
5. I. Aslanov, N. Teshaev, K. Khayitov, U. Mukhtorov, J. Khaitbaeva, and D. Murodova, E3S Web of Conf. **443**, 06015 (2023)
6. O. Ruzikulova and N. Komilova, in (2023)
7. G. Yakubov, K. Mubarakov, I. Abdullaev, and A. Ruziyev, E3S Web of Conferences **227**, 03002 (2021)
8. K. Khakimova, I. Musaev, and A. Khamraliev, E3S Web of Conferences **227**, 02003 (2021)
9. I. Aslanov, I. Jumaniyazov, N. Embergenov, K. Allanazarov, G. Khodjaeva, A. Joldasov, and S. Alimova, in *XV International Scientific Conference "INTERAGROMASH 2022,"* edited by A. Beskopylny, M. Shamtsyan, and V. Artiukh (Springer International Publishing, Cham, 2023), pp. 1899–1907
10. S. Islomov, I. Aslanov, G. Shamuratova, A. Jumanov, K. Allanazarov, Q. Daljanov, M. Tursinov, and Q. Karimbaev, in *XV International Scientific Conference "INTERAGROMASH 2022,"* edited by A. Beskopylny, M. Shamtsyan, and V. Artiukh (Springer International Publishing, Cham, 2023), pp. 1908–1914
11. I. Aslanov, S. Khasanov, Y. Khudaybergenov, M. Groll, C. Opp Ch, F. Li, and R. Del-Valle E, E3S Web of Conferences **227**, 02005 (2021)
12. U. Mukhtorov, I. Aslanov, J. Lapasov, D. Eshnazarov, and M. Bakhriev, in *XV International Scientific Conference "INTERAGROMASH 2022,"* edited by A. Beskopylny, M. Shamtsyan, and V. Artiukh (Springer International Publishing, Cham, 2023), pp. 1915–1921
13. S. Goibberdiev, G. Ikromkhodjaev, Z. Tajekeev, T. Ismailov, U. Mukhtorov, and I. Aslanov, E3S Web of Conf. **443**, 06013 (2023)
14. M. Juliev, L. Gafurova, O. Ergasheva, M. Ashirov, K. Khoshjanova, and M.

https://doi.org/10.1051/e3sconf/202459001011

Mirusmanov, in *Environmental Degradation in Asia*, edited by A. M. F. Al-Quraishi, Y. T. Mustafa, and A. M. Negm (Springer International Publishing, Cham, 2022), pp. 163–176

15. M. Juliev, I. Jumaniyazov, I. Togaev, Sh. Toshtemirov, A. Samiev, I. Ochilov, K. Usmanov, and M. Saidova, E3S Web of Conf. **462**, 03020 (2023)
16. L. Gafurova and M. Juliev, in *Regenerative Agriculture*, edited by D. Dent and B. Boincean (Springer International Publishing, Cham, 2021), pp. 59–67
17. M. Juliev, W. Ng, I. Mondal, D. Begimkulov, L. Gafurova, M. Hakimova, O. Ergasheva, and M. Saidova, E3S Web Conf. **386**, 04010 (2023)
18. A. Bannari, D. Morin, F. Bonn, and A. R. Huete, Remote Sensing Reviews **13**, 95 (1995)
19. M. E. D. Chaves, M. C. A. Picoli, and I. D. Sanches, Remote Sensing **12**, 3062 (2020)
20. A. R. Huete, Remote Sensing of Environment **25**, 295 (1988)
21. S. Bogomazov, A. Lyandenburskaya, A. Levin, E. Efremova, and O. Tkachuk, IOP Conference Series: Earth and Environmental Science **839**, 032025 (2021)