O‘ZBEKISTON RESPUBLIKASI

OLIY TA’LIM, FAN VA INNOVATSIYALAR VAZIRLIGI

FARG‘ONA DAVLAT UNIVERSITETI

FarDU. ILMIY XABARLAR

1995-yildan nashr etiladi
Yilda 6 marta chiqadi

2-2024

НАУЧНЫЙ ВЕСТНИК. ФерГУ

Издаётся с 1995 года
Выходит 6 раз в год

Ж.М.Курбонов, С.С.Сабиров, М.Ж.Курбонова
Исследование предельных напряжений плодов и овощей в процессе конвективной сушки 7
Ж.М.Курбонов, С.С.Сабиров, М.Ж.Курбонова
Конвективная сушка плодов методами предварительного окуривания и бланширования 13
Sh.A.Ashirov, S.T.Boqiyev
Umumiy fizika praktikumlarida eksperimental ko‘nikmalarni rivojlantirish metodikasi..........18
F.D.Jo‘rayev, G‘.X.Maxmatqulov
Yashirin tebranishlarning yaqinlashish sharti asosida raqamli tizim turg‘unligini baholash algoritmi 22
I.D.Yakubov
Separator-tozalagich qurilmasining parametrlari 31

M.A.Axmadaliev, N.M.Yakubova
Иннавацонные пути получения фурано-эпоксидные связующего 34
E.U.Eshchanov, Sh.B.Hasanov, O.I.Xudoyberganov, Z.Sh.Abdullayeva, S.M.Kalandarova, Sh.O.Xo‘sinova
Nikel(II) atsetati hamda qahrabo kislotasining natriyli tuzi bilan kompleksi sintezi va strukturasi 41
G.Q.Otamuxamedova, O.E.Ziyadullayev, F.X.Buriyev, L.Q.Ablakulov, O.E.Boytemirov
Atsetilen spirtlari murakkab efirlari sintezi 48
I.R.Asqarov, G‘.O‘.To‘ychiev
Determination of antiradical activity of plant extracts..........55
A.X.Xaydarov, O.M.Nazarov
Olma o‘simligining makro va mikroelement tarkibini icp-ms usulida o‘rganish 60
N.Y.Saidahmedova
Tut bargi, ipak qurti, pilla va chiqindisi kimyoviy tarkibining qiyosiy tahlili 67
O.K.Asqarova, G.M.Ikromova, E.X.Botirov
Изучение состава эфирного масла надземной части *Salvia deserta* флоры Узбекистана 72
F.B.Eshqurbonov, A.X.Raximov, X.X.Xudoyqulov, M.R.O‘ralova
Tuproqlarda uchraydigan organik uglerod miqdorini “walkley-black” usuli yordamida aniqlash..........78

D.N.Kadirova
Zingiber officinale L. O‘simligini Termiz tumani tuproq iqlim sharoitidagi introduksiyasi..........83
X.S.Umurzaqova, G.M.Zokirova
Farg‘ona vodiysida keng tarqalgan anor zararkunanda hasharotlari (Hemiptera) haqida ma’lumotlar..........86
B.M.Sheraliyev
Orol dengizi havzasi *Sabanejewia* Vladykov, 1929 (Teleostei: Cobitidae) populyatsiyalarining taksonomik tahlili..........92
O.S.Azamov, Sh.A.Xalimov, M.R.Begmatova, Y.Q.Qayumova, D.I.Komilova
Farg‘ona viloyati suv havzalarida tarqalgan *Petroleuciscus squaliusculus* (Kessler, 1872) ning morfometrik ko‘rsatkichlariga asoslangan qiyosiy tahlil..........99
Z.A.Jabbarov, D.P.Jabborova, M.Dustova
Bamiya o‘simligi ildiz tizimining morfologik ko‘rsatkichlariga biochar va mineral o‘g‘itlarning ta’siri 111

FarDU. Ilmiy xabarlar – Scientific journal of the Fergana State University

Volume 30 Issue 2, 2024-yil DOI: 10.56292/SJFSU/vol30_iss2/a127

UO‘K:631.1/631.4

EXPLORING SOIL SALINITY ASSESSMENT METHODS: INSIGHTS, INNOVATIONS, AND THE PROMISE OF REMOTE SENSING FOR SUSTAINABLE AGRICULTURE AND ENVIRONMENTAL CONSERVATION

ИЗУЧЕНИЕ МЕТОДОВ ОЦЕНКИ ЗАСОЛЕНИЯ ПОЧВЫ: ДАННЫЕ, ИННОВАЦИИ И ПЕРСПЕКТИВЫ ДИСТАНЦИОННОГО ЗОНДИРОВАНИЯ ДЛЯ УСТОЙЧИВОГО СЕЛЬСКОГО ХОЗЯЙСТВА И ОХРАНЫ ОКРУЖАЮЩЕЙ СРЕДЫ

TUPROQLARNING SHO‘RLANISHINI BAHOLASH USULLARINI ANIQLASH: TUSHUNCHALAR, INNOVATSIYALAR, VA BARQAROR QISHLOQ XO‘JALIGI VA ATROF-MUHITNI MUHOFAZA QILISH UCHUN MASOFADAN TURIB ZONDLASH

Jabbarov Zafarjon Abdukarimovich[1]
[1]O‘zbekiston Milliy universiteti tuproqshunoslik kafedrasi, biologiya fanlari doktori, professor

Shovkat Kholdorov[2]
[2]O‘zbekiston Milliy universiteti tuproqshunoslik kafedrasi mustaqil tadqiqotchisi

Annotatsiya

Tuproqning sho‘rlanishini baholash qishloq xo‘jaligi barqarorligini ta'minlash va atrof-muhitni samarali boshqarish uchun juda muhimdir. Ushbu maqolada biz tuproq sho‘rlanishini baholashning turli usullarini, shu jumladan dalada sharoitiga asoslangan texnikalarni, laboratoriya tahlil usullarini va masofadan zondlash texnologiyalarini, ularning kuchli tomonlari, cheklovchi omillarini va oqibatlarini hisobga olgan holda baholaymiz. Ushbu usullar orasida masofaviy zondlash iqtisodiy samaradorligi, keng ko‘lamliligi va kelajakdagi rivojlanishlar uchun salohiyati tufayli istiqbolli yondashuv sifatida namoyon bo‘ladi. Tuproqlarning sho‘rlanishini aniqlashda masofadan zondlash texnologiyalari, masalan, sun'iy yo‘ldosh tasvirlari va havodan o‘rganishlar alohida afzalliklarni taqdim etadi, bu katta geografik hududlarni monitoring qilish vositalarini ta'minlaydi va tuproq sho‘rlanish holatlarini o‘z vaqtida aniqlash va xaritalash imkonini beradi. Bundan tashqari, masofadan zondlash multispektral va giperspektral ma'lumotlarni birlashtirishga imkon beradi, bu esa baholash natijalarining aniqliligini oshiradi. Masofaviy zondlash ma'lumotlarining mavjudligi va aqlli algoritmlarning rivojlanishi uning turli xil ekologik holatlarda qo‘llanilishiga yordam beradi. Ushbu taqriz tuproq sho‘rlanishini baholashning muhimligini ta'kidlaydi va tuproq sho‘rlanishining qishloq xo‘jaligi mahsuldorligiga va atrof-muhit barqarorligiga salbiy ta'sirini kamaytirish uchun dalillarga asoslangan boshqaruv strategiyalari haqida ma’lumot berish uchun masofadan zondlash texnologiyalarining imkoniyatlari alohida urg‘u berib ta’kidlanadi.

Abstract

The assessment of soil salinity is crucial for maintaining agricultural sustainability and effective environmental management. In this review paper, we evaluate various soil salinity assessment methods, including field-based techniques, laboratory analysis methods, and remote sensing technologies, considering their strengths, limitations, and implications. Among these methods, remote sensing emerges as a promising approach due to its cost-effectiveness, scalability, and potential for future advancements. Remote sensing technologies, such as satellite imagery and aerial surveys, offer distinct advantages in soil salinity assessment, providing a non-invasive means of monitoring large geographic areas and enabling timely detection and mapping of soil salinity patterns. Moreover, remote sensing allows for the integration of multispectral and hyperspectral data, enhancing the accuracy of assessment results. The accessibility of remote sensing data and the development of intelligent algorithms further contribute to its applicability across diverse environmental contexts. This review highlights the importance of soil salinity assessment and emphasizes the potential of remote sensing technologies to inform evidence-based management strategies for mitigating the adverse effects of soil salinity on agricultural productivity and environmental sustainability.

Аннотация

Оценка засоления почвы имеет решающее значение для поддержания устойчивости сельского хозяйства и эффективного управления окружающей средой. В этом обзорном статье мы оцениваем различные методы оценки засоления почвы, включая полевые методы, методы лабораторного анализа и технологии дистанционного зондирования, учитывая их сильные стороны, ограничения и последствия. Среди этих методов дистанционное зондирование становится многообещающим подходом благодаря его экономической эффективности, масштабируемости и потенциалу для будущих улучшений. Технологии *дистанционного зондирования, такие как спутниковые снимки и аэрофотосъемки, предлагают явные преимущества в оценке засоления почвы, предоставляя неинвазивные средства мониторинга больших географических территорий и позволяя своевременно обнаруживать и картировать закономерности засоления почвы. Более того, дистанционное зондирование позволяет интегрировать мультиспектральные и гиперспектральные данные, повышая точность результатов оценки. Доступность данных дистанционного зондирования и разработка интеллектуальных алгоритмов еще больше способствуют их применимости в различных экологических контекстах. В этом обзоре подчеркивается важность оценки засоления почв и подчеркивается потенциал технологий дистанционного зондирования для обоснования научно обоснованных стратегий управления, направленных на смягчение неблагоприятного воздействия засоления почв на продуктивность сельского хозяйства и экологическую устойчивость.*

Kalit so'zlar: *tuproq, sho'rlanish, sun'iy yo'ldosh tasviri, masofadan zondlash, dalaga asoslangan texnikalar, laboratoriya tahlillari.*
Ключевые слова: *почва, засоление, космический снимок, дистанционное зондирование, полевые методы, лабораторный анализ.*
Key words: *soil, salinity, satellite image, remote sensing, field-based techniques, laboratory analysis.*

INTRODUCTION

Salinization and sodification were identified as one of the top ten threats to soil well-being in the Food and Agriculture Organization (FAO) and the International Technical Panel on Soils (ITPS) collaborative report "Status of the World's Soil Resources" published in 2015 (Intergovernmental Technical Panel on Soils, 2015). The issue under consideration by FAO and ITPS is characterized by an increase in the geographical area affected by salt, coupled with a corresponding escalation in the severity of soil salinity and sodicity, which is rapidly spreading. The growth and survival of diverse plant species are severely threatened by various types of salt-affected soils, such as saline, sodic, and saline-sodic soils, as stated by E. Gamalero (2020). While certain soils affected by salt may possess specific plant species that can provide useful knowledge for enhancing crop resilience against abiotic stress, excessive levels of salt and/or exchangeable sodium may disrupt the delivery of crucial ecosystem services that sustain human existence and biodiversity, as per Hanin (2016). The significance of salt in sustaining human life cannot be overstated. However, the emergence of salt-affected soils and the escalation of salinity and sodicity levels in soils have resulted in numerous unfavorable consequences. These include diminished agricultural productivity, compromised water quality due to groundwater salinization, decreased biodiversity, amplified soil erosion due to reduced vegetation cover and soil structure degradation, reduced capacity of crops to absorb water due to heightened osmotic stress, inadequate or disproportionate availability of micronutrients, and decreased crop yields (Alkharabsheh et al., 2021; Machado & Serralheiro, 2017). The acceleration of salinization and sodification of agricultural land is attributed to climate change, diminished water availability, and unsustainable agricultural practices (Clarke et al., 2018; Hopmans et al., 2021). According to projections, the dryland expansion of the world is expected to increase by 23% by the conclusion of the 21st century, with countries that are developing accounting for 80% of this expansion (Lutz et al., 2018). Given that salinity is more likely to develop in arid climates, the dry regions mentioned above may be at risk of salinity. According to global estimates, human activities have resulted in the salinization of around 77 million hectares of cultivated land (Oldeman et al., 1991). As per the findings of Qadir et al. (2014), the degradation of land caused by salt results in an estimated yearly loss of 27.3 billion USD in agricultural productivity.

The salinity of the soil presents a significant agro-environmental challenge that, year after year, leads to significant losses in both economic and agricultural production (N. Thaker et al., 2021). The prevalence of soil salinity in Uzbekistan is a significant agro-environmental issue. Approximately 50% of the country's irrigated land, which amounts to 4.2 million hectares, is affected by salinity to varying degrees, indicating the widespread nature of the problem (Kholdorov et al., 2022). The heightened soil salinity in the area is attributed to several factors, including the high mineralization and depths of the groundwater table in the region, as well as evaporation rates that surpass the quantity of precipitation received. The issue is exacerbated by the overutilization of mineral fertilizers and suboptimal irrigation techniques, which collectively foster the secondary salinization of agricultural soils in Uzbekistan (Kholdorov et al., 2023). Saline soils present a potential threat not only to agricultural activities but also to the biota inhabiting the soil, including invertebrates, macrofauna, and microbes. The resolution of this significant issue is imperative to sustain the enduring vitality of the soil and overcome the foremost impediment to agricultural efficiency that is presented by soil salinity. Consequently, the restoration of fields damaged by salt is imperative to meet the increasing global demand for food and livestock feed.

Accurate and reliable characterization of saline soils necessitates mapping and monitoring of soil salinity, which provides information on the spatial and temporal distribution of salinity (Hassani et al., n.d.). In order to determine the salinity of the soil, the laboratory employs a number of different methods (Stavi et al., 2021). One of the indicators that are used most frequently to determine the amount of soluble salts that are present in a soil solution is the electrical conductivity (EC) of the soil solution. However, using laboratory results for mapping and monitoring geographical and temporal changes in soil salinity is time-consuming, labor-intensive, and expensive (Asfaw et al., 2018; Maurya et al., 2021). During the past decade, there has been an increase in the utilization of remote sensing methods for the purpose of mapping and monitoring saline soil. Free high-resolution satellite images from Landsat 8, Landsat 7, Sentinel-2, and Sentinel-1 satellites are available for download, specifically for scientific research, particularly in the field of soil analysis utilizing satellite images (Zhu et al., 2019). Numerous studies have used satellite imagery, aerial video imagery, and terrestrial radiometric methods to identify and assess soils impacted by salinity. Remote sensing techniques utilizing intelligent algorithms can offer salinity estimation of surface areas across diverse temporal and spatial domains. Recent studies have utilized multispectral sensors, such as Landsat8 OLI and Sentinel-2A, to ascertain soil salinity levels, specifically in arid and semi-arid regions (Abuelgasim & Ammad, 2019; Günal et al., 2021; Kilic et al., 2022; Liu et al., 2021).

The aim of this review paper is to provide a comprehensive overview of soil salinity assessment methods and their implications for agricultural sustainability and environmental management. By examining different assessment approaches, the paper aims to contribute to a better understanding of soil salinity and inform the development of effective management strategies.

METHODS

For this review paper, we utilized a systematic literature review methodology to comprehensively gather relevant information on soil salinity assessment methods. We conducted exhaustive searches on key academic databases such as PubMed, Web of Science, and Scopus, employing specific keywords related to soil salinity, assessment techniques, agriculture, and environmental management. Our inclusion criteria encompassed peer-reviewed articles, books, reports, and grey literature published within the last decade, ensuring the inclusion of recent and pertinent literature. Through meticulous examination of titles, abstracts, and full texts, we identified relevant studies for data extraction. This process involved systematically capturing key findings related to assessment methods. Subsequently, we synthesized information from diverse sources and critically evaluated the strengths and weaknesses of various assessment approaches, aiming to provide a comprehensive understanding of soil salinity assessment methods and their implications for agricultural sustainability and environmental management.

In addition to the systematic literature review methodology, this review paper incorporates international standards, standard operating procedures (SOPs), and recommendations from prominent international technical committees in the field of soil science. These authoritative sources provide valuable guidance and best practices for soil salinity assessment, ensuring the rigor and reliability of the methods discussed.

LITERATURE REVIEW

Soil salinity analysis holds significant importance due to multiple reasons. Soil salinization assessment is crucial in devising effective management strategies to mitigate its impact and ensure sustainable crop production in the long run. The analysis of soil salinity can furnish insights into the impact of soil salinity on soil health, the ecosystem, and water resources (Aziz et al., 2019). Conducting a soil salinity analysis can enable farmers, land managers, and water managers to make informed decisions regarding the management of soil salinity and its associated impacts.

Field basis soil salinity analysis

The assessment of soil salinity degree is often expeditiously conducted through the utilization of field-based methods for soil salinity analysis. Various techniques are employed, including visual inspection, measurement soil electrical conductivity and soil pH (Table 1), and etc. Namely, the process of visual assessment involves the observation of the physical characteristics of the soil and vegetation within a given field (Singh, 2022). Soil electrical conductivity mapping entails measuring soil electrical conductivity at various locations in the field with a portable EC meter (Meena et al., 2019). Soil salinity levels can also be estimated using soil pH measurements. However, soil pH measurements alone may not provide an accurate measure of soil salinity (Hardie & Doyle, 2012). It is important to acknowledge that field-based techniques offer a preliminary approximation of soil salinity and must be employed in tandem with laboratory-based techniques to ensure a precise evaluation.

Table 1. Some examples of portable apparatus for estimating soil salinity in field condition.

Equipment name and short description	Picture	Source
COMBI 5000 - Activity measurement (salinity) Salinity is determined by the concentration of total dissolved salts directly in the soil or substrate, taking into consideration the relevant soil properties, like soil moisture, temperature, and soil compaction.		https://www.stepsy-stems.de/en/prod-ucts/ph-value-and-salinity/combination-equipment/combi-5000/
LAQUAtwin Compact Conductivity meter - measuring the conductivity of soil allows farmers and agronomists to determine optimum fertiliser usage and check the 'health' of soil after salt water damage		https://www.hobo-dataloggers.com.au-/horiba-ec-11-ec-22-ec-33
EM-38 Ground Conductivity Meter. The EM-38 is not specifically designed to measure soil salinity directly. It primarily measures the apparent electrical conductivity (ECa) of the soil, which is influenced by various factors including salinity, soil moisture, and clay content.		www.geonics.com

However, these methodologies can be advantageous in identifying areas within the field that may require additional examination.

Soil sampling and laboratory analysis

Soil sampling and laboratory analysis are considered the most precise and reliable method for determining soil salinity levels. Soil samples are collected from the agricultural or other type land and transferred to laboratory examination utilizing diverse methodologies. To conduct soil sampling and laboratory analysis of soil salinity, the following steps can be taken: Identify the sampling locations → Collect soil samples → Mix soil samples → Air-dry the soil samples → Crush and sieve the soil samples → Preparing Extract → Measurement needed salinity values. There exist multiple techniques in the laboratory that can be employed to ascertain the level of salinity in soil. The methods that are most frequently employed for assessing soil salinity are the electrical conductivity (EC) method, chloride (Cl^-) method, sodium adsorption ratio (SAR) method, and total dissolved solids (TDS) method. The electrical conductivity of the soil is measured using the EC method, which is related to the salt concentration in the soil (Singh, 2022). The EC value is used to calculate the salinity of the soil. The Cl^- method determines soil salinity by measuring the concentration of chloride ions in the soil. The SAR method determines the relative concentrations

of sodium, calcium, and magnesium ions in soil. The sodium-to-other-ion ratio can indicate whether the soil is at risk of sodium toxicity and can help estimate soil salinity. The TDS method determines the total amount of dissolved solids in the soil, which includes salts and other minerals, and the TDS value is used to calculate the soil salinity. It is critical to select the appropriate method based on the specific needs and characteristics of the soil under consideration. Calibration and standardization of the chosen method are also necessary to ensure accurate and reliable results.
The evaluation of soil salinity is frequently conducted through the utilization of electrical conductivity (EC) analysis. The electrical conductivity (EC) is a metric used to assess the capacity of a material, such as soil, to conduct electrical current. The electrical conductivity (EC) of soil can serve as a reliable indicator of salinity levels, owing to the fact that the presence of salts in the soil augments its conductivity. The ratios commonly used for conducting electrical conductivity (EC) analysis on soil-water extracts are 1:5 and 1:1 (He Yanbo, 2012). The two ratios commonly used for extracting soil-water samples for the purpose of electrical conductivity (EC) analysis are 1:5 and 1:1. The methodology for the preparation of soil-water extracts and the corresponding extract ratios is as follows.

Procedure for preparing soil-water extract:

- Measure an approximate mass of 100 grams for each soil specimen and transfer it into a sanitized receptacle.
- Subsequently, the container should be filled with distilled water in the prescribed ratios:
- To prepare a 1:5 soil-water extract, 20 grams of soil should be added to 100 mL of water (FAO, 2021b).
- To prepare a 1:1 soil-water extract, it is recommended to combine 50 grams of soil with 50 mL of water (FAO, 2021a).
- The soil and water should be blended uniformly and left undisturbed for approximately 30 minutes to facilitate the dissolution of salts.
- Subsequent to the elapse of a period of 30 minutes, it is recommended to agitate the mixture once more in order to attain a state of homogeneity within the solution.
- The soil-water extract should be subjected to filtration using a fine mesh or filter paper to eliminate any sediment or undissolved particles.

The second step involves EC measurement, which requires the calibration of the EC meter or conductivity probe in accordance with the guidelines provided by the manufacturer.

- Submerge the electrode of the EC meter or probe into the filtered extract of soil-water.
- Subsequently, it is recommended to permit the reading to attain a state of equilibrium, and subsequently document the numerical value of electrical conductivity. The standard unit of measurement for electrical conductivity is commonly expressed in either milliSiemens per centimeter (mS/cm) or deciSiemens per meter (dS/m) (Barker, 1964).

The saturated paste extract is an alternative technique employed to ascertain the saturation extract (ECe) of soil (Kargas et al., 2018), which serves as an indicator of the soil's highest possible salinity threshold. The process of obtaining a saturated paste extract entails the complete saturation of a soil specimen with distilled water, followed by the subsequent extraction of the resulting liquid. Nevertheless, this approach is comparatively intricate and generally employed in specific laboratory environments. Today, the practice of creating a map of saline soils in Uzbekistan is based on laboratory analysis results, soil mapping is conducted at a minimum sample density of one soil profile per 18 hectares, resulting in a frequency of once every five years (Kholdorov et al., 2022). The predominant method utilized in Uzbekistan to determine soil salinity is the soil-water extract method, which involves a ratio of 1:5 (w/v). Various conventional methods in laboratories are used for the identification of anions and cations that contribute to salinity. The analysis involved the determination of various parameters. The total amount of water-soluble salts, also known as dry residue, was measured by weighing the sediment that had been dried by steam. The total alkalinity, represented by HCO_3^-, was determined through titration using H_2SO_4 (0.01). The chloride ion (Cl^-) was measured by titration with Salt Mora, while the sulfate ion (SO_4^{2-}) was determined through the sedimentation method. The calcium ion (Ca^{2+}) and magnesium ion (Mg^{2+}) were measured using the Trilon method, and the sodium ion (Na+) was calculated as the difference between the sum of anions (HCO_3^-; Cl^-; SO_4^{2-}) and the sum of cations (Ca^{2+}, Mg^{2+}) in 100 g of soil. The results were expressed in cmolc kg^{-1}.

Soil salinity analysis using remote sensing.

In the past ten years, there has been a significant increase in the application of remote sensing techniques in the mapping and monitoring of saline soils. The use of remote sensing technology offers several benefits over traditional methods in terms of efficacy, cost-efficiency, and decreased labor demands for monitoring and mapping changes in soil salinity over temporal and spatial scales. The detection of soil salinity and sodicity presents a significant challenge for the utilization of remote sensing methodologies in soil assessment. Several studies have utilized satellite, aerial video imagery, and terrestrial radiometric methods to identify and evaluate soils that have been affected by salinity. Estimating the salinity of the soil across a large area can be accomplished relatively quickly through the use of satellite remote sensing (He et al., 2023). Multiple satellite images can be utilized for the purpose of estimating soil salinity. The following are several frequently utilized examples.

- The European Space Agency (ESA) operates the Sentinel-1 mission, which is a radar satellite mission. The system offers radar-generated imagery that can be utilized for the purpose of approximating soil moisture and salinity levels. Soil salinity information can be obtained through the derivation of backscatter signals from the radar (https://sentinels.copernicus.eu/web-/sentinel/home).
- The estimation of soil salinity can be facilitated through the utilization of multispectral satellite images provided by the Landsat program, which is a collaborative effort between NASA and the United States Geological Survey (USGS). The integration of distinct spectral bands, such as the near-infrared and shortwave infrared bands, can facilitate the identification of fluctuations in soil salinity (https://landsat.gsfc.nasa.gov/).
- The Moderate Resolution Imaging Spectroradiometer (MODIS) is a scientific apparatus that is installed on the Terra and Aqua spacecrafts operated by NASA. The technology offers imagery with a high level of resolution, which can be utilized for the purpose of estimating soil salinity. The utilization of MODIS' thermal infrared bands has the potential to evaluate soil moisture levels, a parameter that exhibits a strong correlation with soil salinity (https://modis.gsfc.nasa.gov/).
- The SMAP mission, initiated by NASA, offers a combination of active and passive microwave measurements to determine soil moisture levels. The aforementioned measurements possess the potential to make an estimation of soil moisture and subsequently, soil salinity. The SMAP dataset's elevated spatial resolution facilitates intricate cartography of soil salinity (https://smap.jpl.nasa.gov/).
- WorldView-3 is a privately owned satellite that is managed by DigitalGlobe for commercial purposes. The technology offers multispectral imagery of exceptional resolution, which can be utilized for the purpose of estimating soil salinity. The attainment of a high spatial resolution facilitates the meticulous cartography of salinity patterns at a regional level. It is noteworthy that the process of approximating soil salinity through satellite imagery frequently necessitates the amalgamation of diverse data reservoirs and modeling methodologies (https://earth.esa.int/-eogateway/missions/worldview).

Several studies investigated the relationship between indicators of soil salinity and the reflection of salt outlet. Remote sensing techniques utilizing intelligent algorithms can be employed at different time intervals to estimate the surface salinity of extensive areas. Several contemporary investigations have employed multispectral sensors such as Landsat-8 OLI and Sentinel-2A to quantify soil salinity, particularly in regions characterized by arid and semi-arid climatic conditions. Delavar et al. (2020) employed a multiple regression model that utilized reflectance measurements from Landat 8 OLI and Sentinel-2A, as well as field samples, to gauge and chart the salinity of the soil in the eastern region of Urmia Lake in Iran. The model yielded R2 values of 0.77 and 0.74, respectively. Hassan and colleagues (2021) successfully detected soil salinity by utilizing salinity indices derived from Landsat 8 OLI satellite imagery. Subsequently, the aforementioned indices were subjected to validation through on-site assessments of electric conductivity (EC, dS/m), revealing a statistically noteworthy association. To enhance temporal resolution, it is possible to synergistically employ Sentinel and Landsat data.

DISCUSSION

In this discussion section, we assess the effectiveness of various soil salinity assessment methods and their implications for agricultural sustainability and environmental management. Field-based techniques, such as visual inspection and soil electrical conductivity measurement, provide immediate on-site assessment but may lack precision compared to laboratory analysis methods, including electrical conductivity and total dissolved solids measurement. While field-based techniques offer practical advantages, laboratory analysis methods yield more detailed and quantitative results, albeit at the cost of being more time-consuming and requiring specialized equipment and expertise. Furthermore, remote sensing technologies, such as satellite imagery and aerial surveys, provide a non-invasive and scalable approach to soil salinity assessment, enabling the monitoring of large geographic areas over time. By comparing the strengths and limitations of each assessment method, we gain insights into their applicability in different contexts and their potential impact on agricultural decision-making processes. Moreover, we emphasize the importance of standardization and collaboration in advancing soil salinity assessment practices, promoting data comparability, and informing evidence-based management strategies to mitigate the adverse effects of soil salinity on agricultural productivity and environmental sustainability. Through such discussions, we contribute to the advancement of soil salinity assessment methodologies and their integration into sustainable agricultural and environmental management practices.

CONCLUSION

In conclusion, the assessment of soil salinity plays a pivotal role in ensuring agricultural sustainability and effective environmental management. Throughout this review, we have evaluated various soil salinity assessment methods, including field-based techniques, laboratory analysis methods, and remote sensing technologies, considering their strengths, limitations, and implications. Among these methods, remote sensing emerges as a particularly promising approach due to its cost-effectiveness, scalability, and potential for future advancements. Remote sensing technologies, such as satellite imagery and aerial surveys, offer distinct advantages in soil salinity assessment. They provide a non-invasive means of monitoring large geographic areas, enabling the timely detection and mapping of soil salinity patterns over time. Moreover, remote sensing allows for the integration of multispectral and hyperspectral data, facilitating the identification of subtle changes in soil salinity levels and enhancing the accuracy of assessment results. Importantly, the accessibility of remote sensing data and the development of intelligent algorithms further contribute to its cost-effectiveness and applicability across diverse environmental contexts.

REFERENCES

1. Abuelgasim, A., & Ammad, R. (2019). Mapping soil salinity in arid and semi-arid regions using Landsat 8 OLI satellite data. *Remote Sensing Applications: Society and Environment*, *13*(December 2018), 415–425. https://doi.org/10.1016/j.rsase.2018.12.010

2. Alkharabsheh, H. M., Seleiman, M. F., Hewedy, O. A., Battaglia, M. L., Jalal, R. S., Alhammad, B. A., Schillaci, C., Ali, N., & Al-Doss, A. (2021). Field crop responses and management strategies to mitigate soil salinity in modern agriculture: A review. In *Agronomy* (Vol. 11, Issue 11). MDPI. https://doi.org/10.3390/agronomy11112299

3. Asfaw, E., Suryabhagavan, K. V., & Argaw, M. (2018). Soil salinity modeling and mapping using remote sensing and GIS: The case of Wonji sugar cane irrigation farm, Ethiopia. *Journal of the Saudi Society of Agricultural Sciences*, *17*(3), 250–258. https://doi.org/10.1016/j.jssas.2016.05.003

4. Aziz, S. A., Zeleňáková, M., Mésároš, P., Purcz, P., & Abd-Elhamid, H. (2019). Assessing the Potential Impacts of the Grand Ethiopian Renaissance Dam on Water Resources and Soil Salinity in the Nile Delta, Egypt. *Sustainability (Switzerland)*, *11*(24). https://doi.org/10.3390/su11247050

5. Barker, R. E. (1964). Suggested units for conductivity. *Nature*, *203*(4943), 513–513.

6. Clarke, D., Lázár, A. N., Saleh, A. F. M., & Jahiruddin, M. (2018). Prospects for agriculture under climate change and soil salinisation. In *Ecosystem Services for Well-Being in Deltas: Integrated Assessment for Policy Analysis* (pp. 447–467). Springer International Publishing. https://doi.org/10.1007/978-3-319-71093-8_24

7. Delavar, M. A., Naderi, A., Ghorbani, Y., Mehrpouyan, A., & Bakhshi, A. (2020). Soil salinity mapping by remote sensing south of Urmia Lake, Iran. *Geoderma Regional*, *22*, e00317. https://doi.org/10.1016/j.geodrs.2020.e00317

8. FAO. (2021a). *Standard operating procedure for saturated soil paste extract*.

9. FAO. (2021b). *Standard operating procedure for soil electrical conductivity, soil/water, 1:5.* http://www.wipo.int/amc/en/mediation/rules

10. Gamalero, E., Bona, E., Todeschini, V., & Lingua, G. (2020). Saline and arid soils: Impact on bacteria, plants, and their interaction. In *Biology* (Vol. 9, Issue 6, pp. 1–27). MDPI AG. https://doi.org/10.3390/biology9060116

11. Günal, E., Wang, X., Kılıc, O. M., Budak, M., Al Obaid, S., Ansari, M. J., & Brestic, M. (2021). Potential of Landsat 8 OLI for mapping and monitoring of soil salinity in an arid region: A case study in Dushak, Turkmenistan. *PLoS ONE*, *16*(11 November). https://doi.org/10.1371/journal.pone.0259695

12. Hanin, M., Ebel, C., Ngom, M., Laplaze, L., & Masmoudi, K. (2016). New insights on plant salt tolerance mechanisms and their potential use for breeding. In *Frontiers in Plant Science* (Vol. 7, Issue NOVEMBER2016). Frontiers Research Foundation. https://doi.org/10.3389/fpls.2016.01787

13. Hardie, M., & Doyle, R. (2012). Measuring soil salinity. *Methods in Molecular Biology*, *913*, 415–425. https://doi.org/10.1007/978-1-61779-986-0_28

14. Hassan, R., Ahmed, Z., Islam, Md. T., Alam, R., & Xie, Z. (2021). Soil Salinity Detection Using Salinity Indices from Landsat 8 Satellite Image at Rampal, Bangladesh. *Remote Sensing in Earth Systems Sciences*, *4*(1–2), 1–12. https://doi.org/10.1007/s41976-020-00041-y

15. Hassani, A., Azapagic, A., & Shokri, N. (n.d.). *Predicting long-term dynamics of soil salinity and sodicity on a global scale*. https://doi.org/10.1073/pnas.2013771117/-/DCSupplemental

16. He, Y., Zhang, Z., Xiang, R., Ding, B., Du, R., Yin, H., Chen, Y., & Ba, Y. (2023). Monitoring salinity in bare soil based on Sentinel-1/2 image fusion and machine learning. *Infrared Physics & Technology*, *131*, 104656. https://doi.org/10.1016/j.infrared.2023.104656

17. He Yanbo. (2012). A review on electrical conductivity (EC) as a soil salinity indicator. *Journal of Soil Science and Plant Nutrition*, *12*(2), 279–291.

18. Hopmans, J. W., Qureshi, A. S., Kisekka, I., Munns, R., Grattan, S. R., Rengasamy, P., Ben-Gal, A., Assouline, S., Javaux, M., Minhas, P. S., Raats, P. A. C., Skaggs, T. H., Wang, G., De Jong van Lier, Q., Jiao, H., Lavado, R. S., Lazarovitch, N., Li, B., & Taleisnik, E. (2021). Critical knowledge gaps and research priorities in global soil salinity. In *Advances in Agronomy* (Vol. 169, pp. 1–191). Academic Press Inc. https://doi.org/10.1016/bs.agron.2021.03.001

19. Intergovernmental Technical Panel on Soils. (2015). *Intergovernmental Technical Panel on Soils. Status of the world's soil resources: Main report. Food and Agriculture Organization of the United Nations.*

20. Kargas, G., Chatzigiakoumis, I., Kollias, A., Spiliotis, D., Massas, I., & Kerkides, P. (2018). Soil salinity assessment using saturated paste and mass soil:water 1:1 and 1:5 ratios extracts. *Water (Switzerland)*, *10*(11). https://doi.org/10.3390/w10111589

21. Kholdorov, S., Gopakumar, L., Jabbarov, Z., Yamaguchi, T., Yamashita, M., Samatov, N., & Katsura, K. (2023). Analysis of irrigated salt-affected soils in the Central Fergana Valley, Uzbekistan, using Landsat 8 and Sentinel-2satellite images, laboratory studies, and spectral index-based approaches [Unpublished manuscript]. *Eurasian Soil Science*, *56*(8). http://orcid.org/0000-0001-9394-215X

22. Kholdorov, Sh., Gopakumar, L., Katsura, K., Jabbarov, Z., Jobborov, O., Shamsiddinov, T., & Khakimov, A. (2022). Soil salinity assessment research using remote sensing techniques: a special focus on recent research. *IOP Conference Series: Earth and Environmental Science*, *1068*(1). https://doi.org/10.1088/1755-1315/1068/1/012037

23. Kilic, O. M., Budak, M., Gunal, E., Acir, N., Halbac-Cotoara-Zamfir, R., Alfarraj, S., & Ansari, M. J. (2022). Soil salinity assessment of a natural pasture using remote sensing techniques in central Anatolia, Turkey. *PLoS ONE*, *17*(4 April). https://doi.org/10.1371/journal.pone.0266915

24. Liu, J., Zhang, L., Dong, T., Wang, J., Fan, Y., Wu, H., Geng, Q., Yang, Q., & Zhang, Z. (2021). The applicability of remote sensing models of soil salinization based on feature space. *Sustainability (Switzerland)*, *13*(24). https://doi.org/10.3390/su132413711

25. Lutz, W., Goujon, A., Stonawski, M., & Stilianakis, N. (n.d.). *Demographic and human capital scenarios for the 21st century 2018 assessment for 201 countries.*

26. Machado, R. M. A., & Serralheiro, R. P. (2017). Soil salinity: Effect on vegetable crop growth. Management practices to prevent and mitigate soil salinization. In *Horticulturae* (Vol. 3, Issue 2). MDPI Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/horticulturae3020030

27. Maurya, K., Mahajan, S., & Chaube, N. (2021). Remote sensing techniques: mapping and monitoring of mangrove ecosystem—a review. In *Complex and Intelligent Systems* (Vol. 7, Issue 6, pp. 2797–2818). Springer International Publishing. https://doi.org/10.1007/s40747-021-00457-z

28. Meena, R. P., Karnam, V., Tripathi, S. C., Jha, A., Sharma, R. K., & Singh, G. P. (2019). Irrigation management strategies in wheat for efficient water use in the regions of depleting water resources. *Agricultural Water Management*, *214*, 38–46. https://doi.org/10.1016/j.agwat.2019.01.001

29. N. Thaker, P., Brahmbhatt, N., & Shah, K. (2021). A REVIEW: IMPACT OF SOIL SALINITY ON ECOLOGICAL, AGRICULTURAL AND SOCIO-ECONOMIC CONCERNS. *International Journal of Advanced Research*, *9*(07), 979–986. https://doi.org/10.21474/IJAR01/13200

30. Oldeman, R. A. A., Hakkeling, R. T., & Sombroek, W. G. (1991). *World map of the potential natural vegetation.* International Institute for Applied Systems Analysis.

31. Qadir, M., Quillérou, E., Nangia, V., Murtaza, G., Singh, M., Thomas, R. J., Drechsel, P., & Noble, A. D. (2014). Economics of salt-induced land degradation and restoration. *Natural Resources Forum*, *38*(4), 282–295. https://doi.org/10.1111/1477-8947.12054

32. Singh, A. (2022). Soil salinity: A global threat to sustainable development. In *Soil Use and Management* (Vol. 38, Issue 1, pp. 39–67). John Wiley and Sons Inc. https://doi.org/10.1111/sum.12772

33. Stavi, I., Thevs, N., & Priori, S. (2021). Soil Salinity and Sodicity in Drylands: A Review of Causes, Effects, Monitoring, and Restoration Measures. In *Frontiers in Environmental Science* (Vol. 9). Frontiers Media S.A. https://doi.org/10.3389/fenvs.2021.712831

34. Zhu, Z., Wulder, M. A., Roy, D. P., Woodcock, C. E., Hansen, M. C., Radeloff, V. C., Healey, S. P., Schaaf, C., Hostert, P., Strobl, P., Pekel, J. F., Lymburner, L., Pahlevan, N., & Scambos, T. A. (2019). Benefits of the free and open Landsat data policy. *Remote Sensing of Environment*, *224*, 382–385. https://doi.org/10.1016/j.rse.2019.02.016