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Use of remote sensing technologies in organizing monitoring of the meliorative condition of agricultural lands

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Abstract. This article examines the scientific and practical aspects of using remote sensing technologies and Geographic Information Systems (GIS) in monitoring the meliorative condition of agricultural lands. The study highlights the importance of satellite imagery and vegetation indices in assessing soil salinity, land degradation, and the overall meliorative status of irrigated lands. Spatial analysis and cartographic modeling methods were applied to develop effective approaches for meliorative monitoring. The research findings demonstrate that GIS and remote sensing technologies provide high accuracy, efficiency, and rapid assessment opportunities in the management of agricultural land resources and the detection of degradation processes.

Keywords: Meliorative condition, remote sensing, GIS, monitoring, soil salinity, land degradation, vegetation index, cartographic modeling, agricultural lands.

Аннотация. В данной статье рассматриваются научные и практические аспекты использования технологий дистанционного зондирования и географических информационных систем (ГИС) для мониторинга состояния сельскохозяйственных земель с целью улучшения их плодородия. Исследование подчеркивает важность спутниковых снимков и индексов растительности для оценки засоленности почв, деградации земель и общего состояния орошаемых земель с целью улучшения их плодородия. Для разработки эффективных подходов к мониторингу состояния земель с целью улучшения их плодородия были применены методы пространственного анализа и картографического моделирования. Результаты исследования показывают, что технологии ГИС и дистанционного зондирования обеспечивают высокую точность, эффективность и возможности быстрой оценки при управлении сельскохозяйственными земельными ресурсами и выявлении процессов деградации.

Ключевые слова: Состояние земель с целью улучшения их плодородия, дистанционное зондирование, ГИС, мониторинг, засоленность почв, деградация земель, индекс растительности, картографическое моделирование, сельскохозяйственные земли.

Annotatsiya. Ushbu maqola qishloq xo‘jaligi yerlarining meliorativ holatini kuzatishda masofaviy zondlash texnologiyalari va Geografik axborot tizimlaridan (GAT) foydalanishning ilmiy va amaliy jihatlarini o‘rganadi. Tadqiqotda tuproq sho‘rlanishi, yerlarning degradatsiyasi va sug‘oriladigan yerlarning umumiy meliorativ holatini baholashda sun'iy yo‘ldosh tasvirlari va o‘simlik indekslarining ahamiyati ta'kidlangan. Meliorativ monitoring uchun samarali yondashuvlarni ishlab chiqish uchun fazoviy tahlil va kartografik modellashtirish usullari qo‘llanildi. Tadqiqot natijalari shuni ko‘rsatadiki, GAT va masofaviy zondlash texnologiyalari qishloq xo‘jaligi yer resurslarini boshqarish va degradatsiya jarayonlarini aniqlashda yuqori aniqlik, samaradorlik va tezkor baholash imkoniyatlarini taqdim etadi.

Kalit so‘zlar: Meliorativ holat, masofaviy zondlash, GAT, monitoring, tuproq sho‘rlanishi, yerlarning degradatsiyasi, o‘simlik indeksi, kartografik modellashtirish, qishloq xo‘jaligi yerlari.

Introduction.

Currently, improving the meliorative condition of agricultural lands and reducing degradation processes are considered among the most pressing environmental and socio-economic challenges

worldwide. Soil salinization, waterlogging, rising groundwater levels, erosion, and declining soil fertility negatively affect agricultural productivity and sustainable land use. Under conditions of climate change and increasing water scarcity, the efficient use of land resources and continuous monitoring of their meliorative condition have become highly important.

Traditional land monitoring methods require significant time, labor, and financial resources. Therefore, the application of modern geoinformation technologies and remote sensing data has become one of the priority scientific directions in land management and environmental monitoring. Satellite imagery enables rapid and accurate assessment of land conditions, identification of degradation processes, and development of thematic maps.

Remote sensing technologies allow large territories to be monitored within a short period, while vegetation indices provide valuable information on vegetation cover, soil moisture, and salinity levels. GIS technologies make it possible to integrate, process, analyze, and visualize spatial data for effective cartographic support and decision-making.

Main Objective: The study employed GIS technologies, remote sensing data, and cartographic analysis methods. Satellite imagery from Landsat and Sentinel missions was used as the primary data source. The following methods were applied to assess the meliorative condition of agricultural lands. Calculation of vegetation indices, salinity analysis based on spectral indicators, GIS-based spatial analysis, cartographic modeling, creation of geospatial databases, remote monitoring of degradation processes. NDVI (Normalized Difference Vegetation Index) is a key indicator for determining the density and health of vegetation cover.

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Here: NIR – near-infrared radiation, RED – red spectral radiation.

NDVI valuesThe obtained index was used to evaluate vegetation conditions and the meliorative status of agricultural lands.

The research results demonstrated that remote sensing technologies are highly effective for monitoring the meliorative condition of agricultural lands. Satellite imagery analysis enabled the identification of salinity-affected areas, degraded lands, and territories with low vegetation density.Using GIS technologies, the following spatial layers were developed.

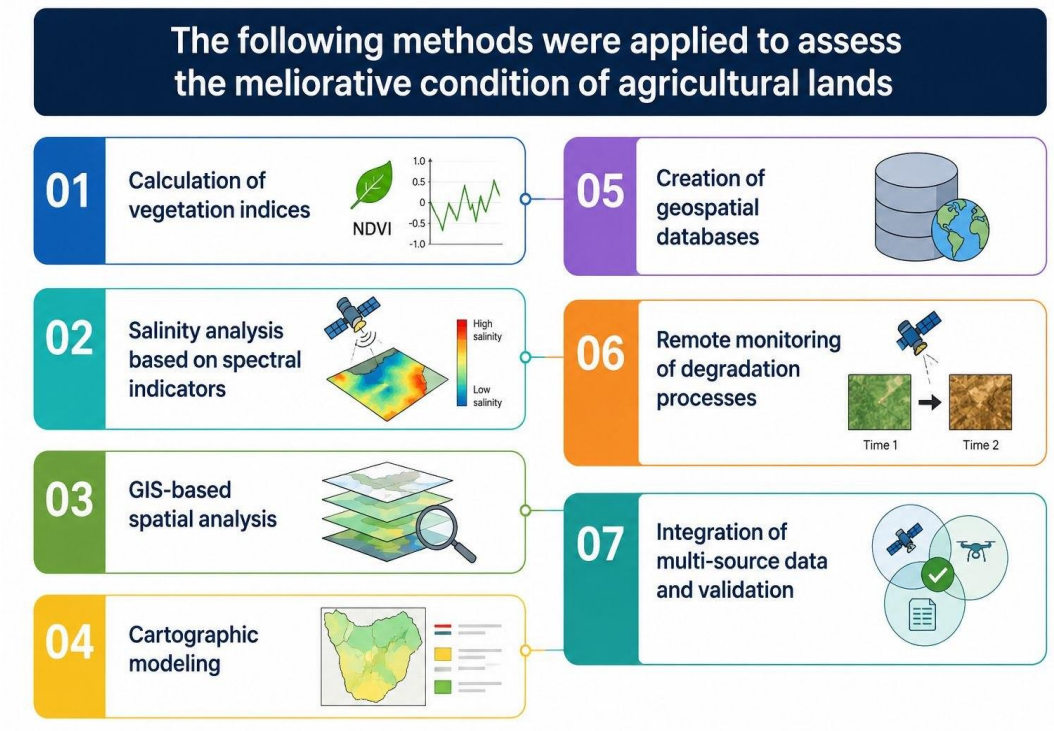

Figure 1. The following methods were applied to assess the meliorative condition of agricultural lands.

Areas with unfavorable meliorative conditions, degradation-prone zones, low vegetation coverage territories, highly saline regions. The study revealed that remote sensing-based monitoring methods have several advantages over traditional approaches, including, rapid data acquisition, high accuracy, cost-effectiveness, capability to cover large territories. Furthermore, thematic electronic maps developed in the GIS environment serve as an important information source for land resource management and planning meliorative measures.

Result.

The research findings demonstrated that the application of remote sensing technologies significantly improves the efficiency and accuracy of monitoring the meliorative condition of agricultural lands. During the study, multi-temporal satellite imagery obtained from Landsat-8 and Sentinel-2 platforms was processed and analyzed using GIS technologies and spectral indices. The obtained results showed that remote sensing data provide an opportunity to identify salinity processes, vegetation stress, moisture deficiency, and degradation dynamics over large agricultural territories within a relatively short time.

The analysis of NDVI (Normalized Difference Vegetation Index) values revealed noticeable spatial differentiation in vegetation cover conditions across irrigated agricultural lands. Areas characterized by low NDVI values corresponded to regions affected by soil salinity, insufficient irrigation, and declining soil fertility. In contrast, territories with higher NDVI values indicated relatively stable meliorative conditions and healthy vegetation growth. This confirms the effectiveness of vegetation indices in assessing agricultural land productivity and ecological stability.In addition, the use of salinity-related spectral indices allowed the identification of saline and moderately saline soils within irrigated areas. The integration of satellite data with GIS-based spatial analysis made it possible to generate thematic maps illustrating the distribution of degraded and melioratively unstable zones. The spatial analysis results indicated that degradation processes are more intensive in regions with poor drainage systems, irrational irrigation practices, and excessive groundwater accumulation.

The study also revealed that remote sensing technologies provide valuable temporal information regarding seasonal and annual changes in land conditions. Through comparative analysis of satellite imagery from different years, the dynamics of land degradation and meliorative changes were effectively monitored. Several territories demonstrated gradual deterioration in soil quality due to long-term anthropogenic pressure and water mismanagement, while some regions showed improvement after the implementation of meliorative measures.

1. Method

Furthermore, GIS-based cartographic modeling enabled the creation of digital monitoring layers representing soil salinity, vegetation condition, moisture distribution, and degradation risk levels. These digital databases support the development of efficient land management strategies and facilitate decision-making processes in agricultural planning and environmental protection.

The obtained results confirmed that the combined use of remote sensing technologies and GIS methods substantially reduces the time, labor, and financial costs associated with traditional field-based monitoring approaches. At the same time, the accuracy and spatial coverage of observations increase significantly, making geospatial technologies highly effective tools for sustainable agricultural land management.

The conducted research highlights the growing importance of remote sensing technologies and GIS methods in modern agricultural land monitoring systems. Traditional methods of assessing meliorative conditions mainly rely on field surveys, laboratory analyses, and ground observations, which often require considerable time, financial resources, and human labor. In contrast, remote sensing technologies provide continuous, large-scale, and оператив monitoring capabilities that allow rapid assessment of land conditions under changing environmental and climatic factors.

The findings of this study are consistent with the results of previous international research, which emphasizes the effectiveness of satellite imagery in detecting soil degradation, salinity, and vegetation stress. Studies conducted by Jensen, Lillesand, Burrough, and other researchers demonstrated that spectral indices derived from multispectral imagery are highly useful for evaluating

agricultural land productivity and environmental sustainability. The present study further confirms that the integration of remote sensing data with GIS-based spatial analysis significantly enhances the reliability of meliorative assessments.

2. Discussion.

One of the most important aspects identified during the study is the role of vegetation indices such as NDVI in evaluating crop conditions and detecting degraded territories. Reduced vegetation activity observed in saline and poorly irrigated areas indicates the strong relationship between soil quality and spectral reflectance characteristics. This relationship enables the identification of problematic zones even before visible degradation symptoms appear in the field.

The study also demonstrated that salinity remains one of the major factors contributing to agricultural land degradation in irrigated regions. Improper irrigation practices, insufficient drainage infrastructure, and rising groundwater levels accelerate soil salinization processes, which negatively affect crop productivity and ecological stability. Remote sensing technologies allow early detection of such processes and support the implementation of preventive meliorative measures.

Moreover, the application of GIS technologies facilitated the development of integrated cartographic models representing multiple environmental factors simultaneously. This approach improves spatial decision-making and enables the creation of digital agricultural monitoring systems capable of supporting sustainable land resource management.

Despite the advantages of remote sensing technologies, several limitations should also be considered. Atmospheric disturbances, cloud cover, image resolution limitations, and seasonal variations may affect the accuracy of satellite data interpretation. Therefore, integrating remote sensing information with field observations and laboratory analyses remains essential for obtaining highly reliable results. Another important issue discussed in this study is the necessity of developing automated monitoring systems based on artificial intelligence, machine learning algorithms, and cloud geospatial platforms such as Google Earth Engine. Such technologies can significantly increase data processing speed and improve the accuracy of degradation forecasting models in future agricultural monitoring studies.

3. Conclusion.

The conducted research confirmed that remote sensing technologies and GIS methods are highly effective tools for organizing and improving the monitoring of the meliorative condition of agricultural lands. The integration of satellite imagery, geospatial analysis, and digital cartographic modeling provides comprehensive opportunities for assessing land degradation processes, soil salinity, vegetation conditions, and irrigation efficiency. The results demonstrated that vegetation indices, especially NDVI, are effective indicators for identifying degraded and melioratively unstable territories. The application of salinity indices and GIS-based spatial analysis enabled accurate mapping of problematic agricultural zones and supported the assessment of environmental risks associated with irrational land use practices.

The study proved that remote sensing technologies significantly reduce the cost and duration of monitoring activities compared to traditional field-based methods while simultaneously increasing spatial coverage and analytical efficiency. The use of multi-temporal satellite imagery also allows continuous observation of land condition dynamics and supports long-term environmental monitoring programs.

Based on the obtained results, it can be concluded that the implementation of GIS and remote sensing technologies contributes to improving agricultural land management, optimizing irrigation systems, preventing soil degradation, and ensuring sustainable use of land resources. The generated thematic maps and digital geodatabases may serve as an important scientific and practical foundation for decision-making processes in agriculture, environmental protection, and territorial planning. In future research, it is recommended to expand the use of high-resolution satellite imagery, unmanned aerial vehicle (UAV) data, machine learning methods, and cloud-based geospatial platforms for automated land degradation monitoring and predictive modeling. The integration of these advanced technologies will further enhance the effectiveness of agricultural monitoring systems and contribute

to sustainable agricultural development under changing climatic and environmental conditions. The use of GIS and remote sensing technologies in monitoring the meliorative condition of agricultural lands has significant scientific and practical importance in sustainable land management. The study confirmed that satellite imagery provides effective opportunities for rapid assessment of soil salinity, land degradation, and vegetation conditions. GIS-based cartographic models and electronic thematic maps contribute to improving meliorative monitoring systems, early detection of degradation processes, and rational use of land resources. Future research should focus on the development of automated geoinformation monitoring systems and the integration of artificial intelligence technologies into agricultural land monitoring processes.

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