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Application and Prospect of Multi-source Remote Sensing Technology Integration in Soil Salinization Monitoring

Hongjian Fan[1, 2, 3, 4, *], Lei Shi[1, 2, 3, 4]

[1]Shaanxi Provincial Land Engineering Construction Group Co., Ltd, Xi'an 710075, China
[2]Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd, Xi'an 710075, China
[3]Key Laboratory of Degraded and Unused Land Consolidation Engineering, Ministry of Natural Resources, Xi'an 710075, China
[4]SHAANXI AGRICULTURAL DEVELOPMENT GROUP CO.,LTD.Xi'an 710075,China

[*] Corresponding author: 729544936@qq.com

Abstract: This study focuses on the application of multi-source remote sensing technology integration in soil salinization monitoring, elaborates on the relevant technical principles, integration methods, and applications, analyzes the challenges and prospects, and provides support for soil salinization monitoring and governance.

Keywords: Multi-source remote sensing technology; Soil salinization; Monitoring; Technology integration.

1. Introduction

Soil salinization seriously restricts global agricultural development and ecological balance. According to statistics from the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Food and Agriculture Organization (FAO) of the United Nations, the global area of saline - alkaline soil reaches 954 million hectares. In China, saline - alkaline soil is also widely distributed, with a total area of approximately 36.93 million hectares [1]. Traditional monitoring relies on field sampling and laboratory analysis, which is inefficient and has a narrow scope, and it is difficult to meet the needs of large - scale and dynamic monitoring [2]. Multi - source remote sensing technology brings new opportunities for soil salinization monitoring.

In recent years, many scholars have carried out research on the application of multi - source remote sensing technology in soil salinization monitoring. Zhang et al. integrated hyperspectral and microwave remote sensing data and used a random forest algorithm to establish a soil salinity inversion model. In a certain arid area, the correlation coefficient between the inversion results and the measured values reached 0.83, and the root mean square error decreased by 12%, significantly improving the monitoring accuracy [3]. However, this technology still faces challenges in practical applications, and in - depth research is of great significance.

2. Multi - source Remote Sensing Technology and Integration Strategies

Multi - source remote sensing technology encompasses optical, thermal infrared, and microwave remote sensing. Optical remote sensing obtains information based on the reflection differences of ground objects in the visible - short - wave infrared bands. Zhao Yingshi pointed out that soil components cause spectral changes in specific bands. It has high spatial resolution and can present small - scale details of soil salinization, but it is easily affected by weather [4]. Thermal infrared remote sensing detects the thermal radiation of ground objects. Based on Planck's law, it reflects soil moisture and other conditions through temperature. Tian Guoliang et al. elaborated that soil moisture affects its thermal characteristics. This technology can obtain soil surface temperature in real - time, which helps to study the movement of soil water and salt. However, its spatial resolution is low and it is affected by the atmosphere [5]. Microwave remote sensing uses the interaction between microwaves and ground objects to obtain information. Shi Jiancheng et al. introduced that it can penetrate clouds, vegetation, and a certain depth of soil. Its scattering and emission are related to the soil dielectric constant, and it has all - day and all - weather observation capabilities. It is sensitive to soil moisture and surface roughness, but data interpretation is complex [6].

Common integration methods of multi - source remote sensing data include pixel - level, feature - level, and decision - level integration. Du Peijun et al. showed that pixel - level integration directly processes the original data, retaining details but being computationally complex and having high requirements for registration accuracy; feature - level integration first extracts features and then integrates them, which can reduce data volume and improve processing efficiency, but the accuracy of feature extraction affects the integration effect; decision - level integration integrates the decision - making results of different data sources, which has strong flexibility and anti - interference ability, but has high requirements for the decision - making accuracy of a single data source [7].

3. Application of Multi - source Remote Sensing Technology Integration in Soil Salinization Monitoring

3.1. Soil Salinity Content Inversion

The research of Zhang et al. provides important reference for multi - source remote sensing technology in soil salinity content inversion. By integrating hyperspectral and microwave remote sensing data and using a random forest algorithm to establish a soil salinity inversion model, good inversion results have been achieved in arid areas, and the monitoring accuracy has been improved [3].

3.2. Analysis of the Relationship between Soil Texture and Salinization

The relationship between soil texture and salinization is close. Although no specific literature is mentioned in the text, the spectral reflectance of optical remote sensing is related to soil particle size. Combining classification algorithms can preliminarily classify soil texture; the soil surface temperature obtained by thermal infrared remote sensing reflects soil thermal inertia, which is related to soil texture and moisture content, providing a basis for analyzing the relationship between them.

3.3. Synergistic Monitoring of Soil Moisture and Salinization

Ma Yajie et al. applied a soil water - salt coupling model integrating multi - source remote sensing data to predict the areas where soil salinization worsened in advance in a certain arid saline - alkaline irrigation area, effectively guiding irrigation and salt regulation, and fully verifying the effectiveness of multi - source data integration in the synergistic monitoring of soil water and salt [8]. Thermal infrared remote sensing estimates the surface moisture content through the thermal inertia model, and microwave remote sensing inverses soil moisture through the backscattering coefficient or brightness temperature. However, both have limitations. By integrating thermal infrared and microwave remote sensing data, the advantages can be combined to improve the soil moisture monitoring accuracy. On this basis, a soil water - salt coupling model can comprehensively consider the coupling relationship between soil moisture and salinity, and more accurately predict the development trend of soil salinization.

4. Challenges and Prospects

Multi - source remote sensing technology integration faces challenges such as large data differences, high integration difficulty, poor model universality, and high data acquisition costs. In the future, new remote sensing sensors such as hyperspectral resolution imagers will provide higher - quality data; artificial intelligence and deep - learning technologies can automatically extract complex features and optimize models; the deep integration of multi - source remote sensing with GIS and GPS, combined with the Internet of Things, will build a more complete monitoring system and provide more powerful support for soil salinization monitoring and governance.

5. Conclusion

Multi - source remote sensing technology integration has great potential in soil salinization monitoring. Although it faces challenges, with the development of technology, it will play a more important role in soil salinization monitoring and governance, providing a guarantee for the rational utilization of land resources and the sustainable development of agriculture. Future research can focus on model optimization, improvement of data integration algorithms, and the application expansion of multi - source remote sensing technology in different ecological environments.

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