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Application of Hyperspectral Remote Sensing Technology in the Inversion of Cultivated Land Quality

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Abstract

This study focuses on the application of hyperspectral remote sensing technology in the field of cultivated land quality inversion. It systematically expounds the principles and characteristics of this technology, deeply analyzes its specific methods and practical application situations in the inversion of cultivated land quality indicators, and verifies its application effects through actual cases. At the same time, it discusses the challenges faced by this technology in practical applications and its future development directions, aiming to provide strong technical support and theoretical references for the efficient and accurate monitoring of cultivated land quality and the sustainable development of agriculture.

Keywords

Hyperspectral Remote Sensing Technology; Cultivated Land Quality; Inversion; Agricultural Development.

1. Introduction

Cultivated land, as the fundamental basis of agricultural production, the accurate assessment of its quality is of crucial strategic significance for the rational allocation of land resources and ensuring national food security. Traditional methods for monitoring cultivated land quality mainly rely on field sampling and laboratory analysis. This method not only consumes a large amount of time and manpower, has low work efficiency, but also makes it difficult to achieve rapid and dynamic monitoring of large - scale cultivated land. With the continuous development of science and technology, the rise of hyperspectral remote sensing technology has provided a new technical means for cultivated land quality monitoring. This technology can obtain rich information of ground objects in continuous spectral bands. With its unique advantages such as high spectral resolution, multiple bands, and high spatial resolution, it can accurately identify and distinguish the subtle differences of surface materials, providing massive and effective data support for the inversion of cultivated land quality - related indicators [1].

In recent years, many scholars have carried out a large number of in - depth studies on the application of hyperspectral remote sensing technology in the inversion of cultivated land quality. For example, a study took a certain area as the research object and used hyperspectral remote sensing technology to invert the cultivated land quality in that area. The researchers first obtained hyperspectral image data and carried out pre - processing operations such as radiometric correction and geometric correction on the data to eliminate radiation errors and geometric distortions caused by factors such as sensor characteristics and atmospheric transmission, ensuring the accuracy of the data. Subsequently, 100 groups of surface soil samples were collected, and the actual content data of soil organic matter, nutrients and other indicators were obtained through physical and chemical analysis. Then, feature extraction and selection algorithms were used to screen out the bands with high correlation with cultivated land quality indicators from the hyperspectral data. Finally, a partial least - squares regression method was adopted to establish an inversion model to invert the soil organic matter and nutrient content in that area. The results showed that the correlation coefficient between the inverted soil organic matter content and the actual measured value reached 0.85, indicating that hyperspectral remote sensing technology has high accuracy and reliability in the inversion of cultivated land quality in that area [2].

There are also studies in some cultivated land areas in the northeastern plain of Shijiazhuang, Hebei Province. By combining the Hapke model, CARS method and support vector machine (SVM) model, an inversion model for cultivated land quality - related indicators was established to invert and estimate indicators such as hydrolyzable nitrogen and organic matter, achieving high accuracy [3]. In the study of the farmland cultivated layer soil in the Jianghan Plain, the researchers explored the hyperspectral response law of soil organic matter by designing a soil organic matter removal experiment. The uve - cars algorithm was used to determine that the 561 - 721nm and 1920 - 2280nm bands are the sensitive bands of soil organic matter. Using these sensitive bands effectively improved the estimation accuracy of soil organic matter [4]. These research results fully demonstrate the feasibility and effectiveness of hyperspectral remote sensing technology in the inversion of cultivated land quality. However, currently, this technology still faces some challenges in practical applications, such as data quality and accuracy issues, data acquisition and processing issues, etc. Therefore, in - depth research on the application of hyperspectral remote sensing technology in the inversion of cultivated land quality has important practical significance and research value.

2. Principles, Characteristics and Application Methods of Hyperspectral Remote Sensing Technology

Hyperspectral resolution remote sensing is a remote sensing system that divides the spectrum into numerous narrow and continuous bands for detection in the ultraviolet to mid - infrared band range. The imaging spectrometer can collect information from hundreds of narrow spectral bands, and then generate a complete spectral curve of the ground object, so as to realize the inversion of the component information of the ground object and the accurate identification of the ground object based on the spectral characteristics of the ground object [5]. This technology has significant characteristics: high spectral resolution enables it to obtain continuous spectral information of ground objects. Each band contains numerous pixels, forming a detailed spectral curve of the ground object, which helps to accurately distinguish different types of ground objects and identify the components of ground objects; the multi - band characteristic enables it to obtain multi - band information simultaneously, significantly improving the accuracy and reliability of ground object identification; high spatial resolution can capture the subtle details of ground objects, providing the possibility for accurate positioning of different cultivated land plots; however, this technology also has the problem of large data volume, which requires strong computing power for data processing and analysis. In addition, hyperspectral remote sensing technology has real - time performance, which can quickly obtain ground object information and facilitate timely decision - making.

In practical applications, first, use hyperspectral remote sensing satellites or aerial platforms to collect hyperspectral image data of cultivated land. Then, perform radiometric correction and geometric correction on the obtained data to eliminate radiation errors and geometric distortions and ensure data quality. Next, extract spectral characteristics related to cultivated land quality from the hyperspectral data, such as spectral reflectance and absorption characteristics, and use feature selection algorithms to remove irrelevant, redundant and interfering information, and screen out the characteristic bands sensitive to cultivated land quality indicators. Finally, comprehensively use statistical methods and machine learning algorithms to construct inversion models for cultivated land quality - related indicators. Common methods include multiple linear regression, partial least - squares regression, support vector machine (SVM), artificial neural network, etc., to achieve the inversion of cultivated land quality [6].

3. Specific Applications of Hyperspectral Remote Sensing Technology in the Inversion of Cultivated Land Quality

3.1. Inversion of Soil Organic Matter Content

Soil organic matter is one of the important indicators for measuring soil fertility, and its content directly affects the water - retaining and fertilizer - retaining capacity, air permeability and microbial activity of the soil. Wang Renchao and others found in their research on hyperspectral remote sensing and its application in agriculture that soil organic matter has obvious absorption characteristics in the near - infrared band (1300 - 2500nm), which is mainly attributed to the vibration absorption of chemical bonds such as C - H, O - H and N - H in organic matter [7]. Subsequently, many researchers have continuously explored effective ways to invert soil organic matter content using hyperspectral remote sensing technology based on this theory. In a large number of research practices, researchers have found through extensive analysis of a large number of soil samples in different regions and combined with various models and algorithms that bands such as 1450nm, 1900nm and 2200nm are more sensitive to changes in soil organic matter content. The correlation coefficient with soil organic matter content reaches 0.88, and the root mean square error is 3.2g/kg, which can estimate the soil organic matter content relatively accurately and provide a scientific basis for the soil fertility evaluation of relevant regions [8, 9].

3.2. Inversion of Soil Nutrient Content

Nutrients such as nitrogen, phosphorus and potassium in the soil are essential elements for the growth of crops, and their content is directly related to the growth status and yield of crops. The research results of Zhao Yuguo and others on soil nitrogen show that nitrogen shows different spectral responses in the visible band (400 - 700nm) and the near - infrared band (700 - 1300nm). In the visible band, nitrogen will affect the content of chlorophyll in the soil, and then affect the spectral reflectance of the soil; in the near - infrared band, nitrogen is related to the vibration of chemical bonds in nitrogen - containing compounds such as proteins and amino acids in the soil, producing specific absorption characteristics. In a study on a wheat - growing area, researchers used hyperspectral data and combined with an artificial neural network model to invert the hydrolyzable nitrogen content in the soil. Through the analysis of training samples and verification samples, the determination coefficient of the model reached 0.82, which can better predict the hydrolyzable nitrogen content in the soil, providing a scientific basis for precision fertilization and helping to improve the utilization rate of nitrogen fertilizer and reduce environmental pollution [2].

For soil phosphorus, the research of Guo Xudong and others found that its spectral characteristics are relatively weak, but there are also certain absorption characteristics in the short - wave infrared band (2000 - 2500nm). Researchers established an inversion model for soil available phosphorus content through the combination of hyperspectral data and chemical analysis. In the application in a certain area, the average relative error between the inversion

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result and the actual measured value is 12.5%, which can meet the needs of monitoring soil phosphorus content in actual production [3].

The spectral characteristics of soil potassium are also relatively complex, and are closely related to clay minerals and potassium - containing minerals in the soil. The research of Zhang Bing and others shows that hyperspectral remote sensing technology can also invert the soil potassium content to a certain extent through the analysis of soil spectra. In some studies, the inversion model of soil available potassium content established using hyperspectral data has achieved good results, providing a reference for the rational application of potassium fertilizer [4].

3.3. Inversion of Soil Texture

Soil texture refers to the composition ratio of different - sized particles in the soil, which has an important impact on the physical properties of the soil such as air permeability, water - retaining capacity and tillability. The research results of Tong Qingxi and others on soil texture show that hyperspectral remote sensing technology can invert and classify soil texture according to the relationship between soil particle size and spectral reflectance. Generally speaking, the finer the soil particles, the lower the spectral reflectance; the coarser the soil particles, the higher the spectral reflectance. The spectral characteristics of soil texture are more obvious in the visible and near - infrared bands. For example, in the study of the soil texture of cultivated land in a certain area, researchers used hyperspectral data and combined with a support vector machine model to classify the soil texture. The soil texture was divided into three categories: sandy soil, loam and clay, and the classification accuracy reached over 85%, which can accurately reflect the distribution of soil texture in that area and provide important information for soil improvement and agricultural production management [5].

3.4. Challenges and Prospects

Hyperspectral remote sensing technology faces many challenges in practical applications. On the one hand, the acquisition of hyperspectral remote sensing data is restricted by factors such as weather conditions and the utilization efficiency of satellite resources, and the data quality and accuracy need to be further improved. The inversion accuracy of crop physiological and biochemical parameters and environmental parameters at the farmland scale can only reach 80 - 90% at most, which cannot fully meet the high requirements of smart agriculture for thematic information of farmland crops and the environment. On the other hand, it is often difficult to obtain effective data when monitoring crops, and it cannot meet the requirements of time resolution and spatial resolution for farmland - scale remote sensing monitoring serving agricultural production management. Especially in areas with more rainy and cloudy weather, the optical images obtained for a long time are often unable to be applied to crop monitoring due to cloud and fog cover. At the same time, the large amount of hyperspectral data requires a large amount of computing resources and efficient algorithms for processing and analysis.

However, with the continuous progress of technology, the performance of hyperspectral remote sensing sensors will be continuously optimized, and the data quality and accuracy are expected to be significantly improved. In the future, multi - source remote sensing data (such as radar remote sensing, thermal infrared remote sensing, etc.) can be combined to achieve complementary advantages and further improve the accuracy and reliability of cultivated land quality inversion. In addition, the application of artificial intelligence and deep learning technology in hyperspectral data processing will be more in - depth, and it is expected to develop more efficient inversion models and algorithms to promote the wide application of hyperspectral remote sensing technology in cultivated land quality monitoring and provide stronger support for the sustainable development of agriculture.

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3.5. Conclusion

Hyperspectral remote sensing technology, with its unique advantages, shows great application potential in the inversion of cultivated land quality. By accurately inverting indicators such as soil organic matter, nutrient content and soil texture, it provides a scientific, rapid and efficient method for the monitoring and evaluation of cultivated land quality. Although there are still some challenges at present, with the continuous development of technology, hyperspectral remote sensing technology will play a more important role in the agricultural field and help to achieve precision agriculture and the sustainable development of agriculture.

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