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Multidimensional Applications of Remote Sensing Technology in Land Use Monitoring and Efficacy Analysis

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Abstract

This article delves into the multidimensional applications of remote sensing technology in land use monitoring and its efficacy. It begins by emphasizing the importance of land resources and the pivotal role of remote sensing technology in monitoring land cover and land use changes. The article then analyzes the application of multi-source remote sensing data, including satellite and aerial remote sensing data, and their use in monitoring at different temporal and spatial scales. The article also examines the accuracy assessment of remote sensing monitoring, factors affecting efficacy, and cost-benefit analysis. Furthermore, it explores the synergistic application of remote sensing technology with GIS and GPS, and summarizes the research findings. Finally, the article points out the deficiencies and limitations of the study and proposes future development trends and research directions.

Keywords

Remote Sensing; Land; Monitoring; Multidimensional Applications; Efficacy Analysis.

1. Introduction

Land resources are the foundation of human survival and development, providing not only basic living materials such as food, fiber, and energy, but also ecological services like water conservation, climate regulation, and biodiversity protection [1]. With population growth and economic development, land resources are under increasing pressure, and irrational land use leads to resource depletion, ecological degradation, and environmental deterioration. Therefore, the rational planning and effective management of land resources become particularly important. Land use monitoring is a key means to achieve this goal, as it can provide information on land cover and land use changes, offering a scientific basis for policy-making and resource management. Remote sensing technology, especially satellite remote sensing, has become an important tool for land use monitoring due to its ability to cover large areas, obtain periodic data, and have high temporal resolution [2]. Remote sensing technology can provide continuous and objective data on land cover and land use changes, which is crucial for monitoring changes in land resources, evaluating the effectiveness of land management policies, and predicting future trends [3]. Moreover, the development of remote sensing technology has also promoted innovation in land use monitoring methods, improving the accuracy and efficiency of monitoring [4]. The main objective of this study is to explore the multidimensional applications of remote sensing technology in land use monitoring and to

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conduct an in-depth analysis of its efficacy, aiming to provide more precise and efficient technical means for the field of land use monitoring, in support of the sustainable management and utilization of land resources.

2. The Multidimensional Applications of Remote Sensing Technology in Land Use Monitoring

2.1. Application of Multi-source Remote Sensing Data in Land Use Monitoring

Satellite remote sensing data play a significant role in land use monitoring due to their extensive coverage and ability to obtain periodic data. High-resolution and medium-resolution data provided by satellite series such as the Gaofen series and the Landsat series can monitor changes in land cover and land use. The application characteristics of these data include the ability to provide continuous time series information, which is crucial for understanding trends and patterns in land use change [5]. For instance, by fully exploiting all available time series Landsat data through remote sensing cloud computing platforms and utilizing the unique phenological information of crops, it is possible to extract agricultural land use information. Aerial remote sensing data, especially unmanned aerial vehicle (UAV) remote sensing data, play an increasingly important role in land use monitoring due to their high resolution and flexibility. UAVs can provide images at the centimeter level, which is very valuable for applications requiring high-precision monitoring, such as urban land use change monitoring and land use in specific development areas. The fusion of multi-source remote sensing data combines data from different sensors, resolutions, and times to improve the accuracy and reliability of land use monitoring [6]. For example, the integration of optical and radar data can improve the extraction of land use and cover information, such as combining L-band PALSAR data with optical data to extract and monitor changes in forest information in China. The advantage of this method is that it can overcome the limitations of a single data source and provide more comprehensive monitoring results.The section headings are in boldface capital and lowercase letters. Second level headings are typed as part of the succeeding paragraph (like the subsection heading of this paragraph).

2.2. Application of Land Use Monitoring at Different Time Scales

Long-term land use change monitoring can reveal the evolutionary process of land use over time. Remote sensing technology can provide long time series data, which is crucial for understanding trends and patterns in land use change. For example, remote sensing data has been used to reconstruct the urban expansion process over the 70 years since the founding of the People's Republic of China, achieving fine-scale mapping of impervious surfaces and green space components in Chinese cities at a 30-meter resolution. Short-term land use dynamic monitoring is particularly important for rapidly changing land use types, such as seasonal changes in crop planting areas. Remote sensing technology can provide periodic monitoring data, helping managers to timely understand short-term changes in land use and make corresponding management decisions [7]. For instance, phenology-based classification methods have been used for the automatic extraction of large-scale rice planting area information.

2.3. Application of Land Use Monitoring at Different Spatial Scales

Regional land use monitoring usually involves large geographical areas, such as provinces, cities, or watersheds. Remote sensing technology provides an effective means to monitor land use changes in these areas. For example, remote sensing data can monitor land use changes, land degradation, and land resource management, assisting governments in land resource planning and management. Local land use monitoring focuses on specific small areas, such as development zones or ecological protection areas. Refined remote sensing technologies, such

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as UAV remote sensing, can provide high-resolution images, which are very useful for monitoring local land use changes and assessing the effectiveness of land management measures [8]. These technologies can help managers make more precise land use decisions at a small scale.

3. Efficacy Analysis of Remote Sensing Technology in Land Use Monitoring

3.1. Accuracy Assessment

In the results of remote sensing monitoring of land use, accuracy assessment is an important indicator for measuring the effectiveness of monitoring. Common evaluation indicators include the confusion matrix and the Kappa coefficient. The confusion matrix is a very intuitive method for displaying the relationship between classification results and actual values, thereby calculating the accuracy of classification. The Kappa coefficient is a statistical measure used to assess the performance of classifiers, taking into account the random consistency of classification results, making it more reliable than simple percentage accuracy. The accuracy of different remote sensing methods and data sources in land use monitoring may vary. For example, Landsat multi-spectral satellite imagery has been used for remote sensing mapping of land use in China's coastal zones, with overall accuracies of 95.16% and 93.98% for the years 2010 and 2015, respectively, and Kappa coefficients of 0.9357 and 0.9229, respectively, demonstrating high mapping accuracy. This indicates that different remote sensing data and methods have varying efficacies in land use monitoring, and choosing the appropriate data sources and methods is crucial for improving monitoring accuracy [9].

3.2. Analysis of Factors Affecting Efficacy

The quality of remote sensing data directly affects monitoring efficacy. High-resolution data can provide more detailed surface information, which helps to improve the accuracy of monitoring. The presence of noise can affect the accuracy of the data, so pre-processing steps are needed to reduce the impact of noise and increase the reliability of monitoring results [10]. Data processing algorithms have a significant impact on the efficacy of remote sensing monitoring. For instance, the accuracy of classification algorithms directly affects the identification of land use types. Change detection algorithms are used to identify changes in land use and cover, and their performance directly affects the results of change detection. External environmental factors, such as weather and terrain, also affect the efficacy of remote sensing monitoring. For example, cloud cover may hinder the acquisition of satellite imagery, and complex terrain may lead to shadowing and perspective issues, affecting the interpretation of images.

3.3. Cost-Benefit Analysis

The costs involved in remote sensing technology for land use monitoring include data acquisition costs and data processing costs. With the convenience and reduced cost of remote sensing data acquisition, as well as the development of technologies such as cloud computing, data processing costs are also gradually decreasing, making the application of remote sensing technology in land use monitoring more cost-effective [11]. Compared to traditional land use monitoring methods, remote sensing technology provides a more efficient and accurate means of monitoring. It can quickly cover large areas and provide periodic data, which is crucial for timely updating land use information and assessing the effectiveness of land management policies. Moreover, remote sensing technology can effectively improve mapping efficiency and the accuracy of land use change detection by integrating multi-source data and expert knowledge-assisted manual-computer interactive interpretation methods [12].

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4. Synergy of Remote Sensing Technology with Other Technologies in Land Use Monitoring

4.1. Integration of Remote Sensing Technology with Geographic Information Systems (GIS)

Geographic Information Systems (GIS) play a crucial role in the processing and analysis of remote sensing data. GIS provides a platform that enables the effective storage, retrieval, analysis, and visualization of remote sensing data. Through GIS, remote sensing images can be transformed into geographically referenced data, allowing for spatial analysis and modeling, which is essential for understanding land use changes and planning land resource management. The integration of remote sensing technology and GIS in land use monitoring offers significant advantages. This integration can provide more accurate land use classification, enhance the monitoring capability of land cover changes, and support more effective resource management and decision-making [13]. For example, in the national dynamic remote sensing monitoring system for land use, GIS and remote sensing technology are combined to achieve rapid monitoring of land use conditions in key areas and specific targets, providing services for comprehensive national land management.

4.2. Synergy of Remote Sensing Technology with the Global Positioning System (GPS)

The Global Positioning System (GPS) provides precise spatial location information for remote sensing data, which is crucial for calibrating remote sensing data and conducting ground validation. GPS data can help ensure the accurate registration of remote sensing images and provide precise geographic locations during ground validation, thereby improving the accuracy and reliability of land use monitoring. The combination of remote sensing technology, GIS, and GPS has a wide range of applications in enhancing the precision of land use monitoring. This "3S" technology integration can provide more comprehensive land use information, including the location, type, and changes of land. For instance, by integrating various new technological methods such as synthetic aperture radar measurement, high-resolution satellite remote sensing, unmanned aerial vehicle (UAV) remote sensing, and airborne laser radar measurement, it is possible to accurately identify geological disaster risk points, enhancing disaster prevention, mitigation management capabilities, and modernization levels. Additionally, using low-altitude UAVs and multi-temporal remote sensing monitoring methods can improve the three-dimensional detection channels and disposal patterns for illegal activities, enhancing the scientific and timeliness of natural resource law enforcement supervision [14]. These practices demonstrate that the synergistic application of remote sensing, GIS, and GPS in land use monitoring has significant benefits, providing more accurate and efficient monitoring results.

5. Conclusion and Prospects

5.1. Summary of Research Findings

This study has summarized the multidimensional applications of remote sensing technology in land use monitoring, including the effective integration of multi-source remote sensing data which has improved the accuracy and efficiency of land use monitoring. The monitoring applications at different temporal and spatial scales have demonstrated the flexibility and adaptability of remote sensing technology. The integrated application of remote sensing technology with GIS and GPS has significantly enhanced the accuracy and reliability of land use monitoring. Accuracy assessment and efficacy analysis have provided an in-depth understanding of the performance of remote sensing technology, offering a basis for further technological improvements and applications. The main findings of the efficacy analysis reveal

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that the accuracy of remote sensing monitoring is affected by data quality, processing algorithms, and external environmental factors. Cost-benefit analysis indicates that remote sensing technology offers high cost-performance in land use monitoring, especially in terms of data acquisition and processing costs. However, the development and application of remote sensing technology still need to address technical challenges and practical operational issues.

5.2. Research Limitations and Insufficiencies

The insufficiencies and limitations of this study are mainly reflected in the theoretical models that may not cover all factors affecting land use change, a possible dependency on certain remote sensing data sources which limits the universality of the results, and a potential lack of extensive validation under different geographical regions and climatic conditions.

5.3. Future Development Outlook

In the future, research and improvements can be strengthened in the development of new algorithms and models to enhance the automated processing and analysis capabilities of remote sensing data, the construction of a robust ground validation network to increase the accuracy of remote sensing monitoring results, the exploration of remote sensing technology applications in emerging fields such as urban expansion, ecological protection, and climate change monitoring, and the enhancement of interdisciplinary cooperation by integrating knowledge from fields such as ecology, geography, and environmental science to achieve more comprehensive land use monitoring.

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