

Research on Ecological Environment Monitoring and Protection Applications Based on Remote Sensing Technology

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Abstract: As global ecological and environmental issues become increasingly severe, remote sensing technology, as an effective monitoring tool, plays a crucial role in ecological environment monitoring and protection. Remote sensing technology can provide large-scale, high-resolution data, supporting a wide range of applications such as ecosystem health assessment, land use/land cover change monitoring, biodiversity conservation, water resource management, pollution monitoring, and climate change monitoring. This paper reviews the application progress of remote sensing technology in ecological environment protection, analyzes the challenges and development trends it faces, and discusses potential directions for future research.

Keywords: Remote Sensing Technology, Ecological Environment Monitoring, Ecological Protection, Environmental Change, Biodiversity.

1. Introduction

Global ecological and environmental issues are becoming increasingly severe, with land use changes, climate change, and environmental pollution emerging as major challenges faced by humanity [1,2]. These issues not only affect biodiversity and ecosystem services but also directly threaten the sustainable development of human society. Land use changes, particularly activities such as agricultural expansion, urbanization, and deforestation, have led to significant ecological degradation and the waste of natural resources. Climate change, driven by factors such as greenhouse gas emissions and global warming, is affecting global climate patterns and leading to an increase in extreme weather events. Environmental pollution, especially water, air, and soil pollution, has had a profound impact on public health and ecosystems. Therefore, how to effectively monitor and assess changes in the ecological environment has become a central issue in global environmental protection and sustainable development strategies [3].

Although traditional ground-based monitoring methods can provide localized ecological and environmental data to some extent, their spatial coverage is limited, and the data collection period is relatively long. Especially in large-scale ecological monitoring tasks, traditional methods often face challenges such as high costs, low efficiency, and discontinuous time intervals. For example, while ground surveys can provide high-precision monitoring results for localized areas, they are often unable to cover vast geographic regions due to the large workload and financial constraints [4]. More importantly, ground-based monitoring typically cannot provide real-time data collection, making it difficult to meet the rapid response demands for ecological and environmental changes. These limitations make traditional monitoring methods inadequate for addressing global environmental changes. Remote sensing technology, by utilizing imagery obtained from satellites, drones, and airborne platforms, can provide real-time and comprehensive information on changes occurring on the Earth's surface. It is widely applied in

ecological environment monitoring, protection, and assessment. The advantages of remote sensing technology lie in its efficiency, broad coverage, and non-intrusiveness, enabling it to provide reliable data support for environmental decision-making and policy formulation [5].

This study will review the application of remote sensing technology in ecological environment monitoring and protection from multiple perspectives, including ecosystem health assessment, land use change monitoring, biodiversity conservation, water resource monitoring, pollution monitoring, and climate change monitoring.

2. Overview of Remote Sensing Technology

Remote sensing technology obtains the properties of surface objects by detecting the electromagnetic wave information reflected or emitted by the Earth's surface features [6]. Remote sensing data can be classified into various types based on differences in spatial resolution, temporal resolution, and spectral resolution. Common remote sensing platforms include satellites, drones, and airborne platforms, among which satellite remote sensing is widely used in global environmental monitoring. (1) Satellite Remote Sensing: Satellites such as Landsat, Sentinel, and MODIS provide data with varying spatial and spectral resolutions, enabling support for large-scale ecological environment monitoring. (2) Drone Remote Sensing: In recent years, drones have become an effective tool for local ecological monitoring due to their high resolution, high flexibility, and low cost. (3) Aerial Remote Sensing: Airborne platforms provide medium to high-resolution remote sensing imagery, suitable for detailed monitoring of specific areas. Remote sensing data processing methods include image preprocessing, classification, change detection, and spatiotemporal analysis. In recent years, with the development of machine learning and deep learning technologies, the automation capability for processing remote sensing data has gradually improved.

3. Application of Remote Sensing Technology in Ecosystem Health Assessment

Ecosystem health assessment is one of the core components of ecological environment monitoring. It primarily evaluates the state of ecosystems by monitoring key ecological parameters such as vegetation cover, surface temperature, and water quality [7]. The application of remote sensing technology in this field is mainly reflected in the following aspects. (1) Vegetation Monitoring: By using vegetation indices such as NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index), the vegetation cover and growth conditions can be quantitatively analyzed, thereby assessing the productivity and health of ecosystems [8]. (2) Surface Temperature Monitoring: By using thermal infrared remote sensing data, changes in surface temperature can be monitored, allowing for the analysis of temperature's impact on ecosystems. For example, temperature variations significantly affect factors such as water evaporation and soil moisture. (3) Wetland and Waterbody Ecosystem Monitoring: The health of wetland and waterbody ecosystems is crucial to the overall ecological environment. Remote sensing technology can assess the health of aquatic ecosystems by monitoring factors such as waterbody area, turbidity, and algal blooms. For example, Landsat data has been widely used for monitoring ecosystem health, such as global-scale forest cover change and wetland degradation. Through long-time series data analysis, researchers can reveal the dynamic changes of ecosystems, providing scientific evidence for ecological conservation.

4. Application of Remote Sensing Technology in Land Use/Land Cover Change Monitoring

Land use and land cover change (LULCC) are important indicators of ecological and environmental changes, and the application of remote sensing technology in this field has achieved significant results [9]. Remote sensing imagery provides high spatial resolution data, enabling effective identification of land use changes and dynamic monitoring. The application of remote sensing technology in LULC (Land Use/Land Cover) monitoring is mainly reflected in the following aspects. (1) Land Cover Classification: Remote sensing data can be classified using methods such as Maximum Likelihood, Support Vector Machines (SVM), and Random Forests to classify the Earth's surface and identify different land cover types, such as cropland, forest, grassland, water bodies, and others. (2) Change Detection: By comparing remote sensing imagery from different time periods, land use changes can be monitored, revealing the impacts of activities such as land reclamation, urbanization, and deforestation on the ecological environment. (3) Dynamic Monitoring: High-frequency remote sensing data, such as MODIS and Sentinel-2, can provide regularly updated land cover information, supporting long-term land use monitoring. For example, using Landsat imagery, researchers can monitor changes such as urban expansion, agricultural expansion, and deforestation in developing countries like China and India [10]. Through remote sensing data, the impact of human activities on the ecological environment can be analyzed, providing scientific support for land management and planning.

5. Application of Remote Sensing Technology in Biodiversity Conservation

Biodiversity is a crucial guarantee for ecosystem functions, and changes in biological habitats have a direct impact on species diversity and ecological balance. The application of remote sensing technology in biodiversity conservation is mainly reflected in the following aspects. (1) Habitat Monitoring: Remote sensing data can help identify and monitor the spatial distribution of biological habitats, as well as assess the quality and changes of these habitats. High-resolution imagery can be used to monitor phenomena such as habitat fragmentation and degradation [11]. (2) Endangered Species Habitat Protection: Through remote sensing technology, the habitats of specific species can be monitored, helping to formulate targeted conservation measures. For example, monitoring of special habitats such as tropical rainforests and wetlands can provide real-time data support for the protection of endangered species. (3) Ecological Corridor Monitoring: Ecological corridors are important pathways for species migration and gene flow. Remote sensing technology can help monitor the connectivity and conservation status of these ecological corridors. For example, in tropical rainforest studies, remote sensing technology has helped reveal the impact of deforestation on biodiversity conservation and provided data support for habitat restoration [12].

6. Application of Remote Sensing Technology in Water Resource Management

The rational management of water resources is crucial for ecological environment protection. The application of remote sensing technology in water resource management primarily includes the following aspects: water body monitoring, flood early warning, drought monitoring, and water quality assessment. (1) Water Body Monitoring: Remote sensing technology can monitor the area, changes, and water quality of water bodies in real time. By analyzing the spectral characteristics of water bodies, remote sensing can identify phenomena such as water pollution and algal blooms. (2) Drought and Water Scarcity Monitoring: Remote sensing data can predict drought-prone areas and water scarcity conditions by monitoring soil moisture, precipitation, and other relevant information. (3) Flood Monitoring and Early Warning: Remote sensing technology can monitor changes in water levels and the extent of flooding before and after a flood event, providing support for disaster early warning and disaster risk reduction efforts. For example, MODIS data has been widely used to monitor global water body changes, providing long-term continuous data support and offering strong evidence for water resource management and protection [13].

7. Application of Remote Sensing Technology in Pollution Monitoring

Application of Remote Sensing Technology in Pollution Monitoring [14]. (1) Air Pollution Monitoring: Remote sensing technology can assess air quality by analyzing the concentration of pollutants such as aerosols, sulfur dioxide (SO₂), and PM_{2.5} in the atmosphere. For example, TROPOMI (Tropospheric Monitoring Instrument), which

obtains atmospheric pollution data from satellite sensors, is widely used to monitor air pollution on a global scale. (2) Water Pollution Monitoring: Remote sensing technology can identify pollutants in water bodies, such as suspended particles and algal blooms, by monitoring the spectral characteristics of the water. (3) Soil Pollution Monitoring: Remote sensing imagery, combined with ground data, can assess the extent and severity of soil pollution, particularly in monitoring heavy metal contamination and agricultural pollution.

8. Application of Remote Sensing Technology in Climate Change Monitoring

Climate change is one of the biggest challenges facing the global ecological environment. Remote sensing technology is primarily applied in climate change monitoring in areas such as temperature changes, glacier retreat, and sea level rise. (1) Temperature Monitoring: Remote sensing data can be used to monitor surface temperature changes, providing quantitative data for climate change research. (2) Glacier Retreat Monitoring: Remote sensing technology can help monitor changes in glaciers in polar and mountainous regions, revealing the impact of climate change on glaciers. (3) Sea Level Change Monitoring: Remote sensing technology can support sea level rise monitoring by tracking changes in coastlines, ocean temperature variations, and other relevant parameters.

9. Challenges and Future Directions of Remote Sensing Technology

Despite significant progress in the application of remote sensing technology for ecological and environmental monitoring, several challenges remain. These include the high cost of data acquisition and processing, the complexity of the technology, and the variability in data quality. In the future, the development of remote sensing technology will primarily focus on the following aspects. (1) Data Fusion and Integration: Integrating data from different sources and with different resolutions to enhance the accuracy and reliability of monitoring. (2) Artificial Intelligence and Deep Learning: Integrating deep learning techniques to automate the analysis and extraction of remote sensing data, improving monitoring efficiency. (3) Multi-scale Monitoring: Combining data from different spatial and temporal scales for comprehensive ecological and environmental monitoring.

10. Conclusion

The application of remote sensing technology in ecological and environmental monitoring and protection is of significant importance. Through remote sensing technology, ecological and environmental changes can be efficiently and accurately monitored, providing scientific evidence for ecological conservation and environmental management. Although remote sensing technology still faces challenges in areas such

as data processing, accuracy, and application scope, with ongoing technological advancements, remote sensing will play an increasingly important role in ecological and environmental monitoring and protection.

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