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The Impact and Significance of Satellite Remote Sensing in Coastal Wetlands

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Abstract. This article systematically reviews the application impact and core value of satellite remote sensing technology in the research of coastal wetlands, focusing on its practical application in three key areas: invasive species monitoring, ecosystem service assessment, and dynamic change detection. According to the research, the combination of multi-source remote sensing data, such as high-resolution satellites and the Landsat series, with advanced technologies like deep learning can effectively achieve high-precision extraction and long-term dynamic tracking of coastal wetland information, significantly enhancing the scientificity and timeliness of wetland governance, ecological restoration, and management decision-making. In invasive species monitoring, satellite remote sensing provides a reliable means for the identification and management effect evaluation of invasive plants over large areas. In the assessment of the net value of ecosystem services, its high-precision classification results lay a data foundation for cost-benefit analysis. In dynamic change detection, the technical approach integrating object-oriented segmentation and deep learning has broken through the limitations of traditional methods, achieving automated and high-precision identification of wetland changes. Overall, satellite remote sensing, with its unique advantages of large-scale coverage, high efficiency, and multi-temporal data, has become an indispensable technical support in the ecological research of coastal wetlands. This article also points out the current challenges faced by the technology, such as the high complexity of data fusion and the limited generalization ability of models, and proposes prospects for future technological optimization and application expansion, with the aim of providing a more solid technical guarantee for the sustainable management of coastal wetlands.

Keywords: Satellite remote sensing technology, coastal wetlands, invasive species monitoring, deep learning

1. Introduction

Coastal wetlands, as a unique ecosystem of the interaction between land and sea, are an important part of the global ecological security framework and possess multiple ecological functions such as conserving water sources, reducing carbon emissions, maintaining biodiversity, and protecting the coast. However, in recent years, due to factors such as biological invasion, urbanization expansion, human development activities, and climate change, global coastal wetlands are facing severe challenges, including shrinking areas and degraded ecological functions [1]. Taking China as an example, in Shandong Province, due to the invasion of Spartina alterniflora, the original native vegetation of coastal wetlands has been severely disrupted. In Tianjin's coastal area, due to land reclamation, the wetland ecosystem has been damaged. Although the Yellow River Estuary Wetland is one of the most complete wetlands in the warm temperate zone, due to the combination of human activities and natural factors, its ecological vulnerability has intensified, so the protection and restoration of wetlands have become urgent.

The traditional wetland survey mainly relies on manual on-site investigation. However, this method has many limitations, such as limited coverage, time-consuming and labor-intensive, and poor timeliness, making it difficult to meet the requirements of large-scale and frequent dynamic monitoring. With the rapid development of satellite remote sensing technology, this problem has been effectively solved. It has high spatial resolution, multi-spectral bands, and multi-temporal observation capabilities, which can not only control the macroscopic situation of coastal wetlands but also conduct microscopic analysis. It can provide precise data from multiple dimensions, such as the distribution of invasive species, the value of ecosystem services, and land use changes. Zhang Xitao et al. precisely grasped the distribution and governance effectiveness of Spartina alterniflora in Shandong Province by integrating multi-source high-resolution remote sensing images and on-site verification, achieving efficient and quantitative monitoring of invasive species on a large scale compared to traditional manual surveys [2]. The team of Jing Junping combined object-oriented segmentation with the UNet deep learning model (eCognition, segmentation scale 40 + shape weight 0.8) to achieve automated and high-precision land use change detection in Tianjin coastal wetlands, with its accuracy (precision, recall rate, F1 score ranging from 0.87 to 0.91) significantly superior to traditional manual interpretation methods [3]. Currently, satellite remote sensing has been widely applied in coastal wetland research and has become the core technical support for evaluating wetland ecological conditions and formulating protection strategies. In-depth analysis of its application impact and importance is of great significance for promoting the sustainable management of coastal wetlands [4].

Therefore, this paper systematically reviews the application status and value of satellite remote sensing technology in key areas of coastal wetlands. By analyzing typical research cases, this paper systematically clarifies the implementation paths and prominent advantages of remote sensing technology in the monitoring of invasive species, the assessment of the net value of ecosystem services, and the detection of dynamic changes. On this basis, it discusses the current challenges and future development trends of the technology, with the aim of providing technical references and decision support for the scientific protection and management of coastal wetlands.

2. Application of satellite remote sensing in monitoring invasive species in coastal wetlands

The coastal wetland ecosystem is facing numerous threats, and the invasion of alien species is one of the main threats. Spartina alterniflora, as a coastal salt marsh plant, is the only one included in the first batch of the national invasive alien species list in 2003. It has spread on a large scale in the southeastern coast of China and the northern coastal areas. Especially in Shandong Province, since its first introduction in 1989, due to the warm temperate climate, extensive muddy intertidal zone, and the weak competitiveness of local plants, it has rapidly become one of the regions with the most severe invasion of Spartina alterniflora in the country. As of 2021, its total distribution area exceeded 10,000 hectares [5].

Zhang Xitao and others conducted a study on the coastal wetlands in Shandong Province, using high-resolution images from the GF series, Resources 1 satellite, and China-Brazil Resources satellites with a spatial resolution better than 2 meters, and combined with the on-site survey data conducted in September 2022 throughout the province, which included drone aerial photos and latitude and longitude information measured by high-precision RTK equipment [2]. They then completed pre-processing tasks such as radiometric calibration of remote sensing data, atmospheric correction based on the 6S model, and orthorectification based on SRTM90 DEM data. By combining the support vector machine machine learning classification method with manual interactive interpretation, they achieved precise monitoring of Spartina alterniflora in Shandong Province in 2022. Through the data, the detection accuracy of new buildings reached 93.96%, the detection accuracy of wetland water areas increased to 94.03%, and the detection accuracy of demolished buildings reached 95.23% [3]. The results showed that the total distribution area of Spartina alterniflora in Shandong Province in 2022 was 2855.37 ha, which decreased by approximately 72% compared to 2021, and the governance effect was very significant [2]. The regional distribution showed big differences. Weihai City had the largest distribution area, reaching 919.59 ha, accounting for 32.21%, and was mainly concentrated in Lishan Bay. Weifang City (902.9 ha, 31.62%) and Yantai City (654.09 ha, 22.91%) were second, while Rizhao City had the smallest distribution area, only 4.99 ha, accounting for 0.17% [2]. The distribution was still concentrated in muddy intertidal zones such as Laizhou Bay and Dingzi Bay. This study not only confirmed that satellite remote sensing can quickly grasp the spatial distribution and diffusion patterns of invasive species and provide data support for optimizing governance plans, such as the proportion in Dongying City decreased from over 50% to 5.83% after governance, but also constructed an invasion species monitoring framework using multi-source remote sensing and on-site verification, providing a technical paradigm that can be borrowed by other regions across the country [2]. The above research indicates that the advantages of satellite remote sensing technology mainly lie in its ability to monitor the distribution, diffusion dynamics, and governance of Spartina alterniflora through high-resolution images and multi-spectral data.

3. The role of satellite remote sensing in the assessment of the net value of ecosystem services in coastal wetland ecosystems

The measurement of wetland ecological functions, management effectiveness, and restoration priorities hinges on the indicator of ecosystem service net value. Precise data on wetland types and areas is the foundation for estimating this net value. Satellite remote sensing technology, with its advantages of multi-temporal data and high classification accuracy, has become the core data source in this field. Ren Lingqi et al. selected the Yellow River Estuary Wetland (geographical range: 37°36′ - 37°54′ north latitude, 119°00′ - 119°20′ east longitude) as the study area. Using Landsat 8OLI remote sensing images from 2019 to 2022 (spatial resolution: 15m, cloud cover less than 5%), combined with ENVI 5.3 and ArcGIS 10.8 software, they completed preprocessing tasks such as radiometric calibration, atmospheric correction, and image fusion. They used the support vector machine (SVM) classification method to extract wetland types, which include 7 types of natural and artificial wetlands, such as shallow sea areas, salt marshes, reeds, and salt-tolerant cordgrass. The overall classification accuracy was verified through on-site investigation data, reaching 90.04% - 96.79%, with a Kappa coefficient of 0.85 - 0.95, which can meet the data accuracy requirements for net value assessment [6]. Ren Lingqi et al. conducted high-precision classification of the Yellow River Estuary Wetland based on 2019-2022 Landsat images using the support vector machine method, achieving an overall accuracy of over 90%. This laid a reliable data foundation for subsequent value assessment [6]. They systematically evaluated 11 types of ecosystem service values. The results showed that in the study area, the core service types, including biodiversity

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conservation, carbon sequestration, food supply, and wave attenuation and protection, accounted for over 90% of the total net value [6]. Zhang Xitao et al. in Shandong Province's monitoring indicated that through effective governance, the distribution area of salt marshes decreased significantly by approximately 72% within one year. This not only directly changed the composition of wetland vegetation but also indirectly confirmed the profound impact of human intervention on the value flow of regional ecosystem services [2]. These cases collectively highlight the irreplaceable role of satellite remote sensing in the quantitative analysis of ecological value and cost, providing key temporal and spatial evidence for dynamic assessment and management decisions.

4. Breakthroughs of satellite remote sensing in dynamic change detection of coastal wetlands

With the acceleration of urbanization, the land use pattern of coastal wetlands has undergone drastic changes. Traditional change detection methods mainly rely on manual interpretation, which has certain limitations in terms of accuracy and efficiency. However, the combination of satellite remote sensing and deep learning technology has successfully achieved automated and high-precision detection of wetland changes [7]. Jing Junping et al. selected the coastal new town of Tianjin's Zhongxin Ecological City (the geographical coordinates of this area are 38°59′N - 39°13′N, 117°39′E - 117°50′E) as the research area. This area once suffered from reclamation, resulting in a reduction in the area of wetlands. However, in recent years, a number of ecological restoration projects have been implemented, making it a typical research area. The researchers used the 2018 Japanese ALOS satellite image (resolution of 2.5m) and the 2022 Chinese High-Resolution Satellite No.6 image (resolution of 2m), using the ENVI software to complete geometric correction, orthorectification, and image fusion (using IHS transformation, PCA, etc.), and then, using the eCognition software for object-oriented segmentation. Through four sets of parameter experiments (segmentation scale of 20 - 80, shape weight of 0.5 - 0.8), it was verified that the segmentation scale of 40 + shape weight of 0.8 was determined as the optimal solution. This solution can accurately extract the boundaries and types of wetlands, including estuarine wetlands, coastal tidal flats, and shallow sea areas, etc. (secondary classification) [3].

Based on this, the change detection work was carried out using the UNet deep learning model. The input of the model was a 512×512 pixel dual-temporal image block containing the RGB bands. These image blocks were processed through data augmentation, such as normalization and random flipping. The Adam optimizer was used, with a learning rate of 0.001. Combined with the class-balanced cross-entropy loss function, the model was trained for 50 epochs. Then, the model performance was evaluated using precision, recall, and F1 score (0.87 - 0.91). The results showed that the accuracy of newly built buildings in the study area reached 93.96% from 2018 to 2022. The newly built buildings were mainly concentrated in the reclaimed land area east of the coastal avenue. This indicates that the urbanization process is accelerating [3]. The accuracy of the increase in wetland water area was 94.03%, which corresponded to the wetland restoration points in the "Ecological Restoration Plan for the Sino-New Tianjin Eco-City Coastal Filling Project". This confirmed the effectiveness of ecological restoration. However, there were phenomena of wetland degradation in some local areas, and the distribution of demolished buildings was relatively small. The accuracy was 95.23%, suggesting that urban renewal had a limited impact on the wetlands. This study not only constructed an object-oriented segmentation + UNet deep learning change detection technology process, quantified the dual impacts of urbanization and ecological restoration, but also pointed out that the current model has some problems, such as high computational resource requirements, dependence on NVIDIA Tesla V100 GPU, and insufficient generalization [3]. This provides a direction for optimizing the model structure and integrating multi-source data (such as

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SAR radar data). In the future, with the continuous breakthroughs of deep learning in the field of remote sensing information extraction, such automated and high-precision technical frameworks are expected to be generalized and applied in more complex wetland scenarios, further expanding the application scope of satellite remote sensing in wetland dynamic monitoring [3, 8].

5. Conclusion

Through the research in this article, it can be found that the three core areas of invasive species monitoring, ecological value assessment, and dynamic change detection have all deeply integrated satellite remote sensing technology. In the aspect of invasive species monitoring, combining multi-source high-resolution remote sensing with on-site investigation can quickly quantify the distribution of invasive plants and the effectiveness of control measures on a large scale. In the ecological value assessment, through high-precision wetland classification, basic data can be provided for net value estimation, which can support cost-benefit analysis and management decisions. In the change detection, by combining object-oriented segmentation and deep learning, it can break through the limitations of traditional methods and achieve automated and high-precision wetland change recognition.

The significance of satellite remote sensing lies in that it overcomes the problems of narrow coverage, low efficiency, and poor timeliness of traditional surveys, and can provide data support for coastal wetland research, achieving the combination of macro and micro, and the consideration of both static and dynamic aspects. As an indispensable technical means in wetland protection, restoration, and sustainable management, it is necessary to further optimize remote sensing data fusion technology and improve the generalization ability of deep learning models in the future, so as to better cope with complex wetland environments and provide guarantees for the ecological security of global coastal wetlands.

References

[1] Murray, N. J., Phinn, S. R., DeWitt, M., Ferrari, R., Johnston, R., Lyons, M. B., & Fuller, R. A. (2020). The global distribution and trajectory of tidal flats. Nature, 565(7738), 222–225.
[2] Zhang, X., Wang, L., Liu, J., et al. (2022). Monitoring and assessment of the control effectiveness of Spartina alterniflora in Shandong Province based on multi-source remote sensing and machine learning. Acta Ecologica Sinica, 42(15), 6120–6132.
[3] Jing, J., Hou, J., Zhang, P., et al. (2023). Change detection of coastal wetlands based on object-oriented segmentation and UNet deep learning model. Journal of Remote Sensing, 27(4), 812–825.
[4] Liu, J., Kuang, W., Zhang, Z., et al. (2021). Analysis of spatio-temporal changes of coastal wetlands in China from 2015 to 2020. Journal of Remote Sensing, 25(6), 1294–1307.
[5] National Forestry and Grassland Administration. (2022). List of Invasive Alien Species in China (2021) and related distribution report.
[6] Ren, L., Hou, M., & Jiang, D. (2023). Research on ecosystem services of the Yellow River Estuary Wetland based on remote sensing and net value assessment model. Journal of Wetland Science, 21(2), 187–199.
[7] Li, H., Wu, T., & Chen, J. (2022). Classification method of coastal wetlands based on deep learning and high-resolution remote sensing images. Journal of Remote Sensing for Land and Resources, 34(1), 78–85.
[8] Gong, P., Luo, J., Shen, Z., et al. (2021). Research progress and prospects of deep learning in remote sensing information extraction. Journal of Remote Sensing, 25(1), 1–19.