remote sensing

Editorial

Remote Sensing of Coastal Waters, Land Use/Cover, Lakes, Rivers, and Watersheds II

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1. Introduction

Coastal zones, terrestrial expanses, freshwater bodies, and their encompassing watersheds are integral to the Earth's environmental framework. The surveillance of these areas through remote sensing is a cornerstone of contemporary environmental stewardship [1–3]. While each of these geographic features contributes significantly to environmental dynamics, the exploration of their mutual influences is essential for a nuanced understanding of the factors driving ecological shifts. With advancements in remote sensing technologies, there has been an increase in the precision and detail of the data collected from these diverse landscapes, which enables a more effective real-time strategy for monitoring the planet's environmental health [4,5].

The improvements in remote sensing have not only enhanced the quality of observational data but also the frequency and resolution at which this data is acquired. This marks a significant improvement in the ability to observe subtle and rapid environmental changes that may have been previously undetected. Furthermore, advancements in data fusion technologies have revolutionized the way information from various remote sensing devices is combined, ensuring a comprehensive and multi-dimensional view of environmental phenomena [6]. Such integrative approaches facilitate the study of complex environmental systems and their responses to natural and anthropogenic influences.

Therefore, remote sensing has become an indispensable method used in the field of environmental science, offering insights into the progressive nature of ecological alterations and the intricate interactions among various environmental components. Accordingly, this Special Issue seeks to showcase innovative research that harnesses the power of advanced remote sensing techniques. It aims to apply these methods to the monitoring and analysis of coastal regions, land masses, lakes, rivers, and watersheds, as well as to investigate the synergistic effects between them. By doing so, this collection aims to further the scientific community's capacity to discern patterns, assess impacts, and comprehend the intricate mechanisms of environmental change. The ultimate goal is to foster a deeper scientific comprehension that can inform policy and conservation efforts, ensuring the sustainable management of natural resources and the resilience of our planet's ecosystems in the face of change.

The subsequent section introduces the articles featured in this issue, delivering a detailed synopsis that encapsulates the thematic essence and the investigative emphases in this Special Issue.

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2. Overview of the Studies

This Special Issue compiles 22 papers that reflect the cutting-edge research in these study fields. The authors and titles are listed as follows:

1. Maimaiti, B.; Chen, S.; Kasimu, A.; Mamat, A.; Aierken, N.; Chen, Q. Coupling and Coordination Relationships between Urban Expansion and Ecosystem Service Value in Kashgar City. *Remote Sens*. **2022**, *14*, 2557. https://doi.org/10.3390/rs14112557
2. Sharma, R.C. An Ultra-Resolution Features Extraction Suite for Community-Level Vegetation Differentiation and Mapping at a Sub-Meter Resolution. *Remote Sens*. **2022**, *14*, 3145. https://doi.org/10.3390/rs14133145
3. Tian, P.; Liu, Y.; Li, J.; Pu, R.; Cao, L.; Zhang, H.; Ai, S.; Yang, Y. Mapping Coastal Aquaculture Ponds of China Using Sentinel SAR Images in 2020 and Google Earth Engine. *Remote Sens*. **2022**, *14*, 5372. https://doi.org/10.3390/rs14215372
4. Shi, Y.; Huang, C.; Shi, S.; Gong, J. Tracking of Land Reclamation Activities Using Landsat Observations—An Example in Shanghai and Hangzhou Bay. *Remote Sens*. **2022**, *14*, 464. https://doi.org/10.3390/rs14030464
5. Tang, M.; Zhao, Q.; Pepe, A.; Devlin, A.T.; Falabella, F.; Yao, C.; Li, Z. Changes of Chinese Coastal Regions Induced by Land Reclamation as Revealed through TanDEM-X DEM and InSAR Analyses. *Remote Sens*. **2022**, *14*, 637. https://doi.org/10.3390/rs14030637
6. Zhang, H.; Liu, X.; Xie, Y.; Gou, Q.; Li, R.; Qiu, Y.; Hu, Y.; Huang, B. Assessment and Improvement of Urban Resilience to Flooding at a Subdistrict Level Using Multi-Source Geospatial Data: Jakarta as a Case Study. *Remote Sens*. **2022**, *14*, 2010. https://doi.org/10.3390/rs14092010
7. Yu, H.; Gu, X.; Liu, G.; Fan, X.; Zhao, Q.; Zhang, Q. Construction of Regional Ecological Security Patterns Based on Multi-Criteria Decision Making and Circuit Theory. *Remote Sens*. **2022**, *14*, 527. https://doi.org/10.3390/rs14030527
8. Lai, X.; Yu, H.; Liu, G.; Zhang, X.; Feng, Y.; Ji, Y.; Zhao, Q.; Jiang, J.; Gu, X. Construction and Analysis of Ecological Security Patterns in the Southern Anhui Region of China from a Circuit Theory Perspective. *Remote Sens*. **2023**, *15*, 1385. https://doi.org/10.3390/rs15051385
9. Li, H.; Fang, C.; Xia, Y.; Liu, Z.; Wang, W. Multi-Scenario Simulation of Production-Living-Ecological Space in the Poyang Lake Area Based on Remote Sensing and RF-Markov-FLUS Model. *Remote Sens*. **2022**, *14*, 2830. https://doi.org/10.3390/rs14122830
10. Liu, D.; Liu, L.; You, Q.; Hu, Q.; Jian, M.; Liu, G.; Cong, M.; Yao, B.; Xia, Y.; Zhong, J.; et al. Development of a Landscape-Based Multi-Metric Index to Assess Wetland Health of the Poyang Lake. *Remote Sens*. **2022**, *14*, 1082. https://doi.org/10.3390/rs14051082
11. Hu, B.; Zou, L.; Qi, S.; Yin, Q.; Luo, J.; Zuo, L.; Meng, Y. Evaluating the Vulnerability of Siberian Crane Habitats and the Influences of Water Level Intervals in Poyang Lake Wetland, China. *Remote Sens*. **2022**, 14, 2774. https://doi.org/10.3390/rs14122774
12. Li, Q.; Li, W.; Lai, G.; Liu, Y.; Devlin, A.T.; Wang, W.; Zhan, S. Identifying High Stranding Risk Areas of the Yangtze Finless Porpoise via Remote Sensing and Hydrodynamic Modeling. *Remote Sens*. **2022**, *14*, 2455. https://doi.org/10.3390/rs14102455
13. Huang, Y.; Pan, J.; Devlin, A.T. Enhanced Estimate of Chromophoric Dissolved Organic Matter Using Machine Learning Algorithms from Landsat-8 OLI Data in the Pearl River Estuary. *Remote Sens*. **2023**, *15*, 1963. https://doi.org/10.3390/rs15081963
14. Wang, D.; Tang, B.-H.; Fu, Z.; Huang, L.; Li, M.; Chen, G.; Pan, X. Estimation of Chlorophyll-A Concentration with Remotely Sensed Data for the Nine Plateau Lakes in Yunnan Province. *Remote Sens*. **2022**, *14*, 4950. https://doi.org/10.3390/rs14194950
15. Mucheye, T.; Haro, S.; Papaspyrou, S.; Caballero, I. Water Quality and Water Hyacinth Monitoring with the Sentinel-2A/B Satellites in Lake Tana (Ethiopia). *Remote Sens*. **2022**, *14*, 4921. https://doi.org/10.3390/rs14194921
16. Soomets, T.; Toming, K.; Jefimova, J.; Jaanus, A.; Põllumäe, A.; Kutser, T. Deriving Nutrient Concentrations from Sentinel-3 OLCI Data in North-Eastern Baltic Sea. *Remote Sens*. **2022**, *14*, 1487. https://doi.org/10.3390/rs14061487

17. Chen, Y.; Pan, G.; Mortimer, R.; Zhao, H. Possible Mechanism of Phytoplankton Blooms at the Sea Surface after Tropical Cyclones. *Remote Sens.* **2022**, *14*, 6207. https://doi.org/10.3390/rs14246207
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22. Yang, Y.; Sun, M.; Sun, L.; Xia, C.; Teng, Y.; Cui, X. A Characteristics Set Computation Model for Internal Wavenumber Spectra and Its Validation with MODIS Retrieved Parameters in the Sulu Sea and Celebes Sea. *Remote Sens.* **2022**, *14*, 1967. https://doi.org/10.3390/rs14091967.

In this overview, we aim to familiarize readers with the studies featured in this Special Issue by discussing them from five key perspectives: land cover change, ecological environments, wetlands and habitats, water quality, and marine disasters and environmental impacts.

2.1. Landcover Change

Land cover changes occur due to various driving forces, with urban expansion being a primary factor. Maimaiti et al. investigated the relationship between urban expansion (*UE*) and ecosystem service value (*Esv*) through analyzing Landsat TM/ETM+/OLI imagery spanning from 1990 to 2015. They employed the Coupling Degree Model and Coordination Model indices to quantify the coupling and coordination dynamics between *UE* and *Esv*. Their findings indicate that, from 1990 to 2015, there was a significant land use transition in Kashgar, characterized by increased urban development and a decreased amount of agricultural and unused land. Urban expansion was particularly notable during the periods 2000–2005 and 2010–2015, adversely affecting the region's ecosystem service value, which diminished over time. This underscores the urgency for improved conservation measures to uphold ecological security. Although the relationship between *UE* and E_{SV} initially displayed a weak relationship, it has shown signs of strengthening, pointing to a gradual shift towards a more harmonious interaction.

In the realm of land cover classification, the extraction of accurate features is crucial for achieving high precision. Sharma introduced two sets of feature extraction methods for land cover and vegetation mapping: one is a very-high-resolution suite with a 2 m precision, and the other is an ultra-resolution suite with a 0.5 m precision. Despite the scarcity of images, the ultra-resolution suite surpassed the very-high-resolution suite in every testing area, enhancing the classification accuracy by 5.3% using single-date images, and by 4.9% with bi-seasonal images. The ultra-resolution suite's employment of pan-sharpened images and the analysis of texture characteristics facilitates the detailed detection of plant communities at the canopy level, which is critical for identifying patches of small or endangered species. While both suites stand to gain from the incorporation of more images for heightened accuracy, the ultra-resolution suite holds particular promise for applications that are both diverse and expansive in scope.

Tian et al. developed a highly accurate map, with a 93% accuracy rate, of China's coastal aquaculture ponds by leveraging Google Earth Engine and ArcGIS along with Sentinel-1 SAR data from the year 2020. Their research revealed that the total area of these ponds is approximately 6937 km^2, with the densest distributions found in the Shandong, Guangdong, and Jiangsu provinces, particularly around river estuaries and coastal plains. The significance of this mapping lies in its utility for the strategic optimization of fishery layouts, which is essential for maintaining food security. Additionally, the study noted a notable north–south disparity in pond sizes, with the larger ponds typically located in the northern regions and the smaller ones situated in the south.

Reclamation, which involves transforming sea areas into land, serves as a strategic response to land scarcity by enlarging the available terrestrial territory. Shi et al. utilized Landsat imagery to monitor reclaimed areas in a test region encompassing Shanghai and Hangzhou Bay. Their research introduces an innovative approach to observing these transformations, distinguishing between sea filling and sea enclosing through the application of "SEDIMENT" tracking and "Eight-Neighborhood" morphological analysis techniques. This study effectively mapped three decades of reclamation efforts and attained an 83.8% accuracy rate in identifying the chronological sequence of reclamation events.

Over the last two decades, land reclamation has significantly reshaped China's coastal landscape, often creating low-lying areas (less than 10 m above sea level) that are prone to flooding, exacerbated by rising sea levels and climate change. In this Special Issue, Tang et al. analyzed the environmental alterations in twelve Chinese coastal regions from 2000 to 2015 associated with reclamation, using TanDEM-X DEM and InSAR analyses. By employing digital elevation models, their study identifies substantial tracts of newly reclaimed land, particularly in Northern China. Moreover, it evaluates the flood risk in Shanghai by integrating SAR data with hydrodynamic models. The findings indicate a high flood risk in Shanghai's southern districts, which host dense critical infrastructure. This research highlights the value of InSAR technology in assessing the flood risks of coastal areas and emphasizes the necessity for precise data to conduct accurate assessments of flood impacts.

Zhang et al. presented a methodology to appraise the resilience of urban areas to flooding, focusing specifically on the recovery rate of city subdistricts, utilizing Sentinel-1A synthetic aperture radar imagery. In their study, they examined Jakarta, a city prone to flooding, and evaluated the resilience across its 42 subdistricts by augmenting Gross Domestic Product (GDP) data with insights from nightlight satellite imagery. Their use of a principal component analysis identified the topography as the most significant factor affecting resilience. They found that the elevation and slope positively contribute to recovery, while a high population density tends to hinder it. The results of this study offer valuable information that can inform targeted policy interventions aimed at enhancing flood resilience, with a particular emphasis on subdistricts that exhibit lower resilience.

2.2. Ecological Environment

Yu et al. advocated for a landscape ecology perspective to pinpoint the zones essential for ecological preservation in the Yangtze River Delta, an area critical for the region's stability and development. The study zeroes in on the Anhui province, assessing pivotal ecosystem services such as biodiversity, carbon sequestration, and soil and water conservation. Through employing a multi-criteria decision-making tool, specifically, the Ordered Weighted Averaging (OWA) method, the researchers sculpted the spatial configuration for ecological defense. This study delineates both the synergistic and trade-off dynamics among these ecosystem services throughout the province and, in accordance, proposes conservation priorities. It spotlights 121 vital ecological source areas that constitute 30.87% of the province's territory, 250 ecological corridors, and key bottleneck and barrier locations that are crucial for regional ecological security. These findings serve as a knowledge base for crafting potential strategies for ecological restoration and land use planning.

Lai et al. implemented the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) model to assess the distribution of ecosystem services and the degree of ecological sensitivity, while also employing circuit theory to devise ecological security patterns. The findings highlight a contrast in ecosystem service values, with the southwest region exhibiting high values and the northeast region showing low values. The ecological stability of the region relies on 38 identified key areas in the southern part of Anhui, encompassing an area of 5742.79 km^2, predominantly characterized by woodlands and grasslands. The study delineated a network consisting of 63 ecological areas interconnected by corridors, pinpointing 28 critical junctions and identifying 6 bottleneck regions. These critical points are primarily clustered around the cities of Huangshan and Xuancheng, providing a strategic focus for ecological conservation and land management efforts.

Li et al. explored sustainable land development in Poyang Lake, analyzing changes from 1989 to 2020 through Landsat imagery and advanced landscape metrics. Their study predicts how land use might evolve by 2030 under different management scenarios. The findings indicate a notable shift: agricultural and natural areas diminished by 3% and 7%, respectively, while urban spaces expanded by 11%, disrupting ecological connectivity and increasing fragmentation. The preferred integrated scenario forecasts a more equitable land distribution, minimizing ecological loss. The study advocates for improved agricultural methods, efficient urban planning, and cohesive community development to support balanced growth and conservation strategies in the region.

2.3. Wetland and Habitat

The health of Poyang Lake's wetlands, impaired by human activity, is the focus of Liu et al.'s research, which proposes a landscape-based multi-metric index (LMI) for its assessment. Utilizing five metrics linked to ecological integrity and analyzed using Landsat-8 OLI imagery, the LMI classifies the wetland's overall condition as "fair". The conditions deteriorate closer to the shores, while more central areas fare better. Liu et al.'s approach provides land managers with a valuable satellite-assisted means to monitor and potentially improve wetland health, underscoring the significance of local landscape conservation efforts.

Hu et al. offer a novel perspective on the impact of water level changes on Siberian crane wintering grounds at Poyang Lake, employing three decades of remote sensing data to scrutinize the habitat quality at distinct 1 m intervals of water depth. The findings underscore the habitats' acute sensitivity to water level variations, pinpointing 12 m as a crucial threshold for maintaining habitat viability, while levels between 9 and 10 m are deemed ideal for crane congregation. The water levels emerge as a dominant factor, accounting for almost half of the variance in the habitat quality, when considered alongside other variables. This study paves the way for advanced methodologies in monitoring and managing the wetland habitats of migratory birds.

Li et al. leveraged remote sensing data coupled with hydrodynamic modeling to highlight the perils of stranding faced by the Yangtze finless porpoise in Poyang Lake, exacerbated by severe seasonal water level fluctuations. Their research unveils that a significant portion of the porpoises' flood season habitat is left high and dry during the drought season, with a notable increase in habitat fragmentation spanning three decades. The study further documents that, in the dry season, the majority of the habitat is afflicted by shallow waters, not exceeding 1 m in depth, which significantly escalates the risk of stranding. High-risk stranding areas, particularly around the Duchang region, have been pinpointed, aligning with historical stranding events. The insights from this study are critical for enhancing rescue operations and present a model that could be replicated for investigating the stranding threats faced by other freshwater cetacean species.

2.4. Water Quality

Research by Huang et al. harnessed the power of machine learning and satellite imagery to advance our understanding of Chromophoric Dissolved Organic Matter (CDOM) in the Pearl River estuary. Data gathered from a cruise survey underpin the development of predictive algorithms using the spectral bands of the Landsat-8 OLI sensor. The study evaluated several models, including Support Vector Regression and Random Forest, but the XGBoost algorithm emerged as the most effective, demonstrating a high correlation and minimal error between the predicted and observed CDOM concentrations. A crucial finding is the significance of specific sensor band ratios on the estimation accuracy. This approach has enabled the detailed mapping of the spatial distribution of CDOM, revealing how it is influenced by tidal movements and wind conditions. The research marks a significant stride in the utilization of machine learning to decode the complex dynamics of CDOM in marine and estuarine ecosystems.

The study by Wang et al. takes advantage of Sentinel-2 MSI imagery to scrutinize chlorophyll-a levels and their relationship with surface temperatures in the lakes of China's Yunnan-Kweichow Plateau. Their analysis, leveraging the Random Forest regression model, aligns closely with in situ measurements, unveiling a positive correlation between rising temperatures and chlorophyll-a concentrations. The findings bear low error margins, validating the efficacy of remote sensing techniques in tracking and managing eutrophication in lake ecosystems. This research underscores the potential of satellite imagery as a reliable tool for ecological monitoring, offering critical insights for the proactive management of lake health and contributing to the broader understanding of aquatic ecosystems under the stress of climate change.

The research conducted by Mucheye et al. cast a spotlight on the seasonal fluctuations of invasive water hyacinth, alongside pivotal water quality indicators such as chlorophyll-a and total suspended matter, in Ethiopia's largest lake, Lake Tana. Employing Sentinel-2 satellite imagery complemented with advanced processing methodologies, the study meticulously chronicles the expansion of the water hyacinth population, with a particular emphasis on the proliferation seen subsequent to the rainy season. The resulting data elucidate the significant role played by the sediment and nutrient flow in both the deterioration of water quality and facilitating the spread of invasive flora. The study not only demonstrates the efficacy of satellite surveillance in tracing environmental transformations but also accentuates its value in the sustainable governance of freshwater ecosystems against the backdrop of global ecological shifts.

Monitoring nutrients is crucial for controlling eutrophication, especially in delicate environments like the Baltic Sea. In their study, Soomets et al. utilized over 25,000 Sentinel-3 satellite images to chart the levels of total nitrogen (TN) and total phosphorus (TP) in Estonian marine areas over five years. Mapping the TN proved to be more reliable, showing a robust correlation and acceptable error margins, compared to mapping the TP. The study evaluated the nutrient levels across six distinct regions, noting seasonal fluctuations. It highlighted the efficacy of remote sensing in phosphorus-scarce, enclosed marine areas over open seas. The findings affirm that satellite imagery can enhance traditional monitoring practices, providing comprehensive and frequent data coverage.

Chen et al. conducted a study using satellite data, reanalysis, and models to investigate the influence of tropical cyclones on oceanic chlorophyll a (Chl-a) concentrations in the South China Sea. The study discovered that severe tropical storms had a negligible impact on the Chl-a levels. However, typhoons caused a moderate rise in the surface Chl-a levels without altering the Chl-a concentration throughout the water column. On the other hand, super typhoons significantly increased both the surface and depth-integrated Chl-a levels. This indicates that such intense storms may enhance the nutrient and phytoplankton abundance in the ocean by inducing upwelling and the mixing of the water layers.

Wang et al. investigated the effects of back-to-back tropical cyclones, Kyarr and Maha, on the Arabian Sea ecosystem. The study recorded two distinct sea surface temperature cooling events that coincided with chlorophyll a (Chl-a) blooms and the formation of three cold eddies. Post-Cyclone Kyarr, the observed increase in Chl-a was attributed to Ekman pumping and vertical mixing redistributing Chl-a. A more pronounced Chl-a bloom ensued after Cyclone Maha, driven by the upwelling of nutrient-dense waters, which facilitated the proliferation of new phytoplankton. The analysis suggests that while the initial Chl-a surge was a redistribution of existing Chl-a, the subsequent, more intense bloom was fueled by fresh nutrients upwelled from the ocean depths.

2.5. Marine Disaster and Environments

Zou et al. aimed to enhance marine disaster assessment, focusing on phenomena such as storm surges and significant wave events, specifically for China's coastal regions. They created a multifaceted algorithm to analyze how ocean currents and coastal topography influence wave behavior. Utilizing Landsat 8 satellite imagery, they mapped out aquaculture zones along the coast to ascertain their susceptibility to these disasters. When applied to a storm surge event on the Shandong Peninsula, the new system identified a 12% escalation in risk during extreme sea conditions, thereby providing a more precise tool for evaluating and mitigating the impact of marine disasters.

Wang et al. investigated the frequency and severity of marine heatwaves (MHWs) in the Japan/East Sea over the period from 1982 to 2020, using satellite-derived data. Their research underscores the significance of MHWs on aquatic ecosystems and human enterprises. The analysis uncovered that these events typically manifest twice per year, with most being less severe and shorter in duration compared to the global mean of 12.6 days and a temperature anomaly of 2.4 °C. The study also recorded a rising trend in the intensity of MHWs in the region, increasing by 29.62 °C days per decade, which is over twice the global rate. This amplification in intensity is attributed to regional oceanographic processes and could have implications for the thermal interchange between the ocean and the atmosphere, with potential consequences for both marine biodiversity and climate patterns.

In a study by Bai et al., the dynamics of the Qiongzhou Strait's summer westward currents and their role in transporting water to the Beibu Gulf were examined using satellite imagery, simulations, and field data. The researchers uncovered a unique, trident-shaped warm water feature at the strait's western entrance. This pattern arises from minimal water stratification, with strong tidal mixing allowing cold upwelling waters to blend with the warmer gulf waters. The area's topography influences tidal currents and temperature distribution, while wind significantly shapes the thermal dynamics and upwelling intensity on the strait's eastern side.

The study by Yong et al. focused on validating internal wavenumber spectra using satellite data, presenting a model that computes the characteristics of these spectra to better understand the interactions among different oceanic movements. The model includes considerations for current shear instability and bottom topography, which are key in analyzing internal waves and their mechanisms. Validated against MODIS satellite data in the Sulu and Celebes Seas, the model has shown promise for broader applications in gaining insight into the formation, dissipation, and interaction of internal waves within the ocean.

The studies featured in this Special Issue collectively underscore the transformative impact of advanced remote sensing technologies in environmental monitoring and analysis. They highlight the intricate dynamics of land cover changes, ecological environments, wetland and habitat health, water quality, and the impacts of marine disasters on different ecosystems. These research efforts demonstrate the critical role of remote sensing in identifying and understanding rapid and subtle ecological shifts, providing valuable data for sustainable environmental management and policy formulation.

Recently, advancements in remote sensing technology, particularly in the realm of artificial intelligence (AI), have significantly enhanced the synergy between remote sensing data and AI methodologies. This combination has emerged as a crucial aspect in environmental analysis. Utilizing AI models, the extensive data acquired through remote sensing can now be interpreted with greater accuracy [7,8]. This enhanced precision facilitates a more detailed understanding of environmental dynamics, both in coastal regions and inland water bodies. The integration of AI with remote sensing not only improves data analysis but also contributes to a deeper and more nuanced comprehension of environmental changes and patterns.

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