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EDITORIAL

Remote sensing and environmental studies on coastal waters, lakes, rivers, and watersheds

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1 Introduction

Environmental protection plays a critical role in ensuring the sustainable development of economies, particularly in developing countries where the balance between growth and ecological preservation is often delicate. Understanding the mechanisms behind environmental changes is essential for crafting informed policies that promote long-term environmental sustainability (Vitousek, 1992; Kondratyev et al., 2002). Lakes, rivers, watersheds, and coastal ecosystems are especially vulnerable to the impacts of human activities (Borgwardt et al., 2019; Morrice et al., 2008), making these vital water bodies increasingly fragile in the face of expanding urbanization, agriculture, and industrialization (Mondal and Palit, 2022).

However, monitoring these environmental changes poses significant challenges due to the time, effort, and financial resources required. Traditional monitoring methods can be labor-intensive and costly, often limiting the scope and frequency of data collection. In response, the emergence of remote sensing technology has revolutionized environmental monitoring by providing an innovative, cost-effective, and efficient approach for studying large-scale and dynamic ecosystems. Remote sensing offers the ability to gather high-resolution, continuous data over vast areas, making it an indispensable tool in tracking changes in inland and coastal waters and other critical environments (Pricope et al., 2019).

This special issue aims to showcase cutting-edge research that leverages remote sensing technology to address pressing environmental issues, particularly in coastal waters, lakes, rivers, and watersheds. By highlighting the latest advances in remote sensing applications, this issue will reflect the evolving frontiers of research in environmental change and remote sensing fields. Papers featured will focus on a range of topics, including, but not limited to, remote sensing methodologies for monitoring water quality, ecosystem health, climate impacts on aquatic environments, and the interaction between land use and water bodies. These studies will contribute valuable insights into how technological innovations can drive sustainable environmental management and inform policy-making at both local and global scales. Thus, in the following section, we will provide a brief introduction to the papers assembled in this special issue. Each of these contributions presents unique insights and innovative methodologies, showcasing diverse studies in understanding and addressing environmental changes. By summarizing the key findings and approaches of the selected studies, we aim to offer readers a clear perspective on how these research efforts advance our knowledge in environmental monitoring and contribute to the broader field of environmental protection and sustainability.

2 Studies of this issue

Water quality in aquatic environments is a central concern, and remote sensing offers a vital approach for monitoring

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and estimating the concentration of key water quality parameters. Among these, chlorophyll is a crucial indicator, whose levels may be intricately linked to the hydrodynamic properties of the water body. This relationship allows for the assessment of ecological health and nutrient dynamics through the analysis of satellite imagery and sensor data, providing a comprehensive view of aquatic ecosystems. In their study, Chen et al. (2022, this issue) utilized satellite remote sensing to monitor a phytoplankton bloom in the western South China Sea that started in mid-August 2007, prior to the formation of a cyclonic eddy. The analysis reveals a one-week delay between the peak chlorophyll-a (Chl-*a*) concentrations and the maximum intensity of the eddy, a delay possibly linked to the Mekong River discharge and subsequent interactions with the cyclonic eddy. The presence of a dense jet of high Chl-*a* indicates a substantial influx of nutrients from the south-westerly monsoon, crucial for the growth of phytoplankton. This bloom significantly contributes to the distribution of biomass-rich waters to the open ocean, influencing the food chain dynamics of the outer south-eastern shelf and nearby coral islands or atolls. This study may promote the understanding of how eddies contribute to the movement of phytoplankton biomass and nutrients from coastal regions to the open sea, enhancing knowledge of marine ecosystem dynamics in the South China Sea.

During the summer months, the south-western Arabian Sea (AS), particularly off the Somali coast, frequently experiences phytoplankton blooms. These blooms are notably influenced by the strong reversing monsoon and the prevalent upwelling in the region. High concentrations of chlorophyll-a (Chl-*a*) have been consistently documented, spurred by these environmental conditions. To understand the spatial and inter-annual fluctuations of Chl-*a*, Chen et al. (2021, this issue) leveraged satellite data capturing ocean color and wind vectors, examining the mechanisms that drive these variations. The analysis highlighted a significant year-to-year variability in Chl-*a* levels across the south-western AS. Through simple correlation analysis, it became evident that factors like Ekman transport (ET) and Ekman pumping velocity (EPV) are closely linked with these Chl-*a* concentrations. These mechanisms are believed to elevate nutrients from deeper or coastal waters to the surface, thereby boosting Chl-*a* levels, especially off the Somali coast during summer. The upwelling driven by EPV might have a more pronounced effect than that driven by ET, indicating its stronger role in supporting the phytoplankton blooms. Aerosol precipitation also emerged as a critical element, significantly enriching Chl-*a* concentrations in the deep offshore regions of the south-western AS, second only to ET and sea surface temperature (SST), and even exceeding the impact of EPV. The influence of aerosol optical thickness (AOT) is particularly notable in these offshore regions, where dust deposition acts as a key nutrient source for the otherwise nutrient-poor waters. Both the stability of the upper ocean and the input from aerosols were identified as major factors affecting the broader waters off the Somali coast.

Eutrophication and algae blooms are increasingly threatening urban lakes in Hanoi, Vietnam, primarily due to human-induced pollution and climate changes. Vinh et al. (2022, this issue) have formulated an empirical model using Landsat 8 (L8) level 2 data that has been atmospherically corrected with the Land Surface Reflectance Code (LaSRC) algorithm. This model is designed to monitor the trophic state index (TSI) of these lakes. The study involved the analysis of 138 *in situ* TSI measurements gathered from 13 lakes in Hanoi over seven occasions between 2015 and 2020, alongside corresponding L8 reflectance data. A significant logarithmic relationship between TSI and the spectral ratio from the near-infrared band (band 5) to the green band (band 3) was developed, evidenced by a coefficient of determination of 0.65. Validation of the model confirmed its accuracy in estimating TSI in nutrient-rich waters, with a root-mean-square error (RMSE) of 6.6. The utility of the model was further demonstrated through its application to six selected L8 images, which tracked an upward trend in TSI across 25 urban lakes in Hanoi during the study period. L8-LaSRC data surpassed the performance of the Landsat 8 Provisional Aquatic Reflectance Product in monitoring these shallow urban lakes.

Poyang Lake, a major freshwater lake in China, is crucial for the wintering of various wildlife species and significantly contributes to the region's ecological dynamics. Qi et al. (2023, this issue) employed Landsat satellite imagery to track the changes in habitat characteristics of Poyang Lake from 1990 to 2021. To conduct this analysis, four machine learning approaches were utilized: random forest (RF), gradient boosting tree (GBT), support vector machine (SVM), and classification and regression trees (CART), with a focus on evaluating overall accuracy and Kappa coefficients. The random forest method provided the most accurate results. Using the RF approach, detailed changes in the winter habitats at Poyang Lake were mapped. The analysis showed that areas of mudflats were more prevalent than those covered by water or sand. After 2012, there was a noticeable increase in grassland, correlating with the earlier onset of the dry season. Habitat fragmentation was significant between 1990 and 1998, but from 1997 to 1998 onward, there was a discernible reduction in the density and disturbance of landscape patches, indicating lesser impacts from both human activities and natural events on the habitat changes at Poyang Lake.

Tu and Pan (2024, this issue) explored changes in land use and coverage within the Wuhan Metropolitan Area from 1988 to 2023, drawing on an expansive Landsat remote sensing data set and employing advanced machine learning technologies to assess impacts on carbon storage. Among the algorithms evaluated, the Random Forest (RF) algorithm proved to be the most precise, accurately identifying various land use categories with a Kappa coefficient well above

0.98. During this timeframe, significant shifts were observed in the region's landscape, notably a decline in arable spaces and an increase in urban infrastructure, spurred by economic and urban growth. The InVEST model was used to quantify the effects of these land use modifications on carbon sequestration, indicating a substantial reduction in carbon storage capabilities, totaling an estimated 428.59×10^4 tons lost between 1988 and 2023. Primarily, this reduction was driven by the urbanization of lands previously dedicated to carbon-rich forests and farms.

The lack of reliable hydro-climatic data significantly hinders effective stormwater runoff management in rapidly urbanizing areas. The study by Mhina et al. (2021, this issue) examined the role of catchment heterogeneity in assessing vulnerability to stormwater-related hazards in urban areas. Employing GIS techniques, satellite imagery, and field surveys, the geomorphological and hydrological features of the Mbezi River catchment in Dar es Salaam, Tanzania, were analyzed to evaluate their impact on flood risk. The analysis of the catchment's heterogeneity revealed that the Mbezi River catchment has a fern-leaf shape, with a drainage density of 1.9 km/km^2 and features a total relief and elongation ratios of 265 m and 0.25, respectively. This study also identified numerous natural depressions ('blue spots') within the catchment which could potentially retain approximately 18 percent of stormwater runoff, thereby mitigating downstream flooding issues. Notably, 68 percent of these significant sinks (with potential volumes exceeding 2.4 m^3) are situated along the river's floodplain on publicly owned land. In this research, that over 11.6 ha of land and 168 buildings located near these large natural sinks are identified at increased risk of flooding, should these depressions become filled.

Duan et al. (2022, this issue) targeted the spatial and architectural traits of 114 nationally and provincially recognized traditional villages in Fuzhou, Jiangxi Province, China. Employing a blend of methods including field observations, archival explorations, and advanced geographic and spatial syntax analyses, this study dissected the arrangement and nuances of these heritage sites across both expansive and localized perspectives, examining how these two perspectives interact. These villages are predominantly positioned at lower elevations close to water sources, suggesting a non-uniform regional spread. On a more detailed scale, these settlements are primarily of small to medium size, shaped by their proximity to one of eight types of distinctive waterfront hills. Concerning village boundaries, the most common layout features elongated, finger-like extensions, some with linear arrangements and others grouped in clusters. Settlement patterns within these villages are chiefly formed by four unique types of comb-like configurations, reflecting adaptations to the local environment, terrain, and cultural influences.

The study by Wei et al. (2022, thus issue) evaluated the ecological risks from the chemical forms and concentrations of heavy metals (HMs) in Baiyangdian Lake's sediments, providing crucial data for environmental protection in the Xiong'an New Area. Key HMs like As, Cd, Cr, Cu, Pb, and Zn were analyzed in the lake and adjacent river sediments using an improved Tessier five-step method. The ecological risks were assessed with the Risk Assessment Coding Method (RAC) and mean sediment quality guideline quotient (SQG-Q). Findings show HM concentrations in the lake sediments are 1 to 3 times above background levels, highest in the center and lower in the northern and southern areas. The study also noted that sediment physicochemical properties such as pH (6.99 to 7.28) and organic matter content (3.98% to 5.69%) significantly influence HM bioavailability and toxicity. RAC revealed high potential risks for Cd, Pb, and As, while SQG-Q indicated high ecological risks for As, Cr, and Pb. Sources of HMs were linked to human activities, with industrial waste impacting Cu, Zn, and Cd, while Pb mainly originated from community activities. Chromium's sources were more complex, suggesting a variety of origins.

Inland lakes are critical ecological assets, and their monitoring is vital for national development and resource management. Khorshiddoust et al. (2022, this issue) examined the substantial changes in water levels and land use around Urmia Lake and Aral Lake over a 28-year period, with a focus on the impacts of human activity and mismanagement. To analyze these changes, this study utilized Moderate Resolution Imaging Spectroradiometer (MODIS) and Landsat imagery from 1988 and 2018. Object-based image classification was applied to categorize six land types, achieving classification accuracies of 89.23% for Urmia Lake and 92.46% for Aral Lake in 1988, and 85.8% and 95.15% respectively in 2018—well above the 85% threshold for reliable data. The findings reveal a concerning decline in water levels and an increase in salinity for both lakes, linked to the expansion of agricultural and urban areas.

Pei and Pan (2024, this issue) utilized the three-dimensional MIKE model to simulate the hydrodynamic properties of Poyang Lake from October 2020 to December 2021. The model showed high accuracy, with a coefficient of determination (R^2) of over 0.96 for water level and 0.98 for water area, proving its effectiveness in capturing the lake's hydrodynamics. During March and April, a marked pressure gradient forcing was noted, coinciding with increased flow rates from the Ganjiang River on the lake's east side. This created a pronounced pressure gradient front in the central channel of the lake, potentially affecting material distribution. Eddy kinetic energy, derived from model velocity data, reached its peak during May and June, and again in September and October, aligning with river flow variations. This study identified a robust correlation between eddy activities and the spatial distribution of water materials, supported by consistent patterns in turbidity observed in satellite imagery and eddy kinetic energy distributions. These results underscore the crucial role of hydrodynamic processes, especially eddy movements, in influencing the dispersion of suspended materials in Poyang Lake.

Coastal sediments along the Shandong Peninsula, sensitive indicators of climatic shifts, have accumulated in numerous sequences from the Last Glacial Period. These sediments have traditionally been studied for their material sources and climatic features, yet the analysis of monsoon patterns on a ten-thousand-year scale, particularly in relation to sea-level changes, has been less frequent. The Liukuang section (LKS), near the North Yellow Sea, consists primarily of alternating layers of dune sand and paleosol from the Last Glacial. Utilizing a chronology based on AMS ^{14}C and optically stimulated luminescence (OSL) dating, the study of Li et al. (2022, this issue) assessed grain size, geochemistry, and heavy minerals to chart the shifts in the East Asian winter monsoon (EAWM) and associated climate changes during this period. Climate proxy indicators within the sedimentary facies—from dune sand to sandy paleosol, lacustrine deposits, and silty paleosol—suggest variations in the intensity of the dry-cold climate and the strength of the EAWM. Notably, this research identified phases of intensified EAWM during LKS4 (78.9–59.5 ka), LKS3b (50.5–39.6 ka), and LKS2 (29.7–13.1 ka), corresponding to Marine Isotope Stages (MIS) MIS4, MIS3b, and MIS2, respectively. Conversely, weaker EAWM phases occurred during LKS3c (59.5–50.5 ka) and LKS3a (39.6–29.7 ka), aligning with MIS3c and MIS3a. These climatic episodes suggested that changes in solar radiation and a combination of monsoon shifts and sea-level fluctuations are key drivers of these climatic events.

3 Conclusions

This edition features a compelling array of 11 research papers that delved into various dimensions of environmental change, focusing on themes such as water quality remote sensing, the influence of land cover and types, and the dynamics of lake hydrodynamics. Utilizing state-of-the-art technologies and innovative methods, these papers expand our comprehension of the intricate ways environmental elements interact and influence ecosystems at both micro and macro levels. The insights offered in this issue not only push the boundaries of our current understanding of environmental systems but also underscore the critical role that advanced remote sensing and modeling techniques play in monitoring and forecasting ecological shifts. These studies collectively highlight the necessity of cross-disciplinary cooperation and the integration of diverse scientific perspectives. Looking ahead, it is essential that the knowledge acquired from this research informs and shapes policies and practices, steering efforts toward sustainable development and ecological preservation amid the continuously shifting challenges of global change.

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