Mapping and sustainable management of mangrove ecosystems in Buruk Bakul village, Indonesia: integrating high-resolution imagery, spatial analysis, and policy recommendations

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Abstract. This study examines the critical state of mangrove ecosystems in Buruk Bakul village, Indonesia, employing high-resolution satellite imagery and advanced spatial analysis techniques. The research reveals a mangrove cover of 190.0 hectares, with a 9.3 hectares discrepancy from 2021 governmental data, highlighting the urgency for updated mapping methodologies. The study identifies significant fragmentation due to anthropogenic activities, potentially compromising habitat quality and ecological functions. All mangroves fall within the non-forest estate (NFE), facing imminent threats of conversion to industrial and plantation zones according to the Riau Province Spatial Plan. The research underscores the complexities of mangrove management in NFE areas, emphasizing the need for a holistic, synergistic approach amid overlapping ownership and interests. It proposes sustainable management strategies, including community-led conservation, protected area establishment, and the implementation of a lend-use system. The study advocates for strengthening local regulations and fostering collaborative management with stakeholders and communities. By integrating precise mapping, spatial analysis, and policy recommendations, this research provides a comprehensive framework for addressing the challenges of mangrove conservation in the face of developmental pressures, aiming to preserve these ecosystems' vital ecological, economic, and social contributions.

Keywords: Buruk Bakul, mangrove mapping, non-forest estate, sustainable management.

Introduction. Mangroves, vital coastal ecosystems, serve as linchpins of environmental balance (Kelleway et al 2017; Kochoni et al 2023) and offer significant ecological and socio-economic benefits (Arifanti et al 2022). These ecosystems mitigate coastal erosion impact (Raju & Arockiasamy 2022), provide habitats for diverse fish species and marine biota (Nagelkerken et al 2008), and act as carbon sinks (Alongi 2022), underscoring their strategic value. However, mangroves face severe and immediate threats from land encroachment (Jhonnerie et al 2007, 2014), illegal logging (Rudianto et al 2020), and other human activities such as urban development, industrial pollution, and overfishing (Mukherji et al 2022). Protecting and preserving mangrove ecosystems is crucial for maintaining environmental balance and ensuring future generations' access to their ecological and socio-economic benefits (Yllano & Summers 2023).

Comprehensive and accurate mangrove mapping requires high-quality spatial and spectral resolution data. Wang et al (2004) emphasize spatial resolution's crucial role in distinguishing between various mangrove communities. Despite the existence of high-quality satellite imagery such as RapidEye (Oktorini et al 2013), SPOT 6 (Jhonnerie et al

2015), QuickBird (Neukermans et al 2008), and WorldView (Kanniah et al 2013), challenges related to procurement and processing costs persist. Non-technical factors like cloud cover and shadows pose severe obstacles to research, especially for projects with limited resources (Li et al 2022). Utilizing freely available high-resolution satellite images offers a cost-effective solution with substantial advantages (Hu et al 2013). This approach becomes relevant in light of the extensive and global threat of mangrove degradation (Goldberg et al 2020), which can drastically alter mangrove ecosystems' composition, structure, and function (Carugati et al 2018).

Very-high-resolution imagery services are accessible through standalone applications like Google Earth Pro (García Calva et al 2019) or plugins and web services integrated with geographic information systems. These services facilitate gathering training area data for classification and accurately assessing land cover and land-use mapping (Islami et al 2022). A vital advantage lies in their capacity to provide ultra-high-resolution data in red-green-blue (RGB) format, potentially enriched with details such as texture, tone, and geometric features. This capability aids in compiling mangrove maps and enhances visual and digital representations (Hu et al 2013).

Mangroves significantly affect surrounding areas' biological and socio-economic aspects (Eddy et al 2016). Integrating accurate mapping with regional spatial planning enables the identification of critical locations requiring protection and restoration while providing space for sustainable human activities. This integration paves the way for developing ecotourism, wetland restoration, and sustainable use, thus providing long-term benefits (Nguyen et al 2019). The legal status and management of mangrove forest areas significantly affect these ecosystems' sustainability (Arifanti et al 2022). A deep understanding of existing regulations and policies and community-based management approaches can strengthen mangrove forest protection and ensure sustainable use, empowering local communities.

This research aims to map mangroves using high-resolution satellite imagery and develop opportunities for sustainable mangrove management. Integrating mapping and spatial planning information with the legal status of mangrove forest areas enables the identification of protection gaps and proposing policy improvements. This approach contributes to developing more effective mangrove conservation and sustainable use strategies, offering the potential for preserving and restoring these vital ecosystems.

Material and Method

Description of the study sites. The study encompasses an 8-kilometer coastline in Buruk Bakul village, extending from 101°47'59.259″ E, 1°26'37.215" N to 102°5'1.198" E, 1°21'32.354" N (Figure 1), directly overlooking the Bengkalis Strait. The local mangrove ecosystem functions as a crucial buffer for the Terubuk fish (*Tenualosa macrura*) sanctuary in Riau Province, contributing significantly to Terubuk fisheries sustainability and overall mangrove ecosystem health (Seygita et al 2022). Notable mangrove species in this area include: *Acrostichum aureum*, *Avicennia alba*, *Bruguiera gymnorhiza*, *Ceriops tagal*, *Excoecaria agallocha*, *Nypa fruticans*, *Rhizophora apiculata*, *R. mucronata*, *Sonneratia alba*, *S. caseolaris*, *S. ovata*, *Scyphipora hydrophylacea*, *Xylocarpus granatum*, and *X. moluccensis*.

Data. The research methodology employs a comprehensive approach, utilizing diverse datasets to analyze mangrove distribution and density in Buruk Bakul Village. Data sources include high-resolution satellite imagery from July 2020, accessed via QGIS application with QuickMapServices plugin, and Sentinel-2 Level 2A satellite imagery from March 23, 2024, obtained through the Google Earth Engine platform. The 2021 National Mangrove Spatial Data, provided by the Ministry of Environment and Forestry (KLHK) (Direktorat Konservasi Tanah dan Air 2021), Directorate of Land and Water Conservation, contributes to mangrove density attributes categorized as sparse, medium, or dense. Additionally, the study incorporates Riau Province spatial planning data for 2018-2038, detailing forest status and spatial planning attributes.

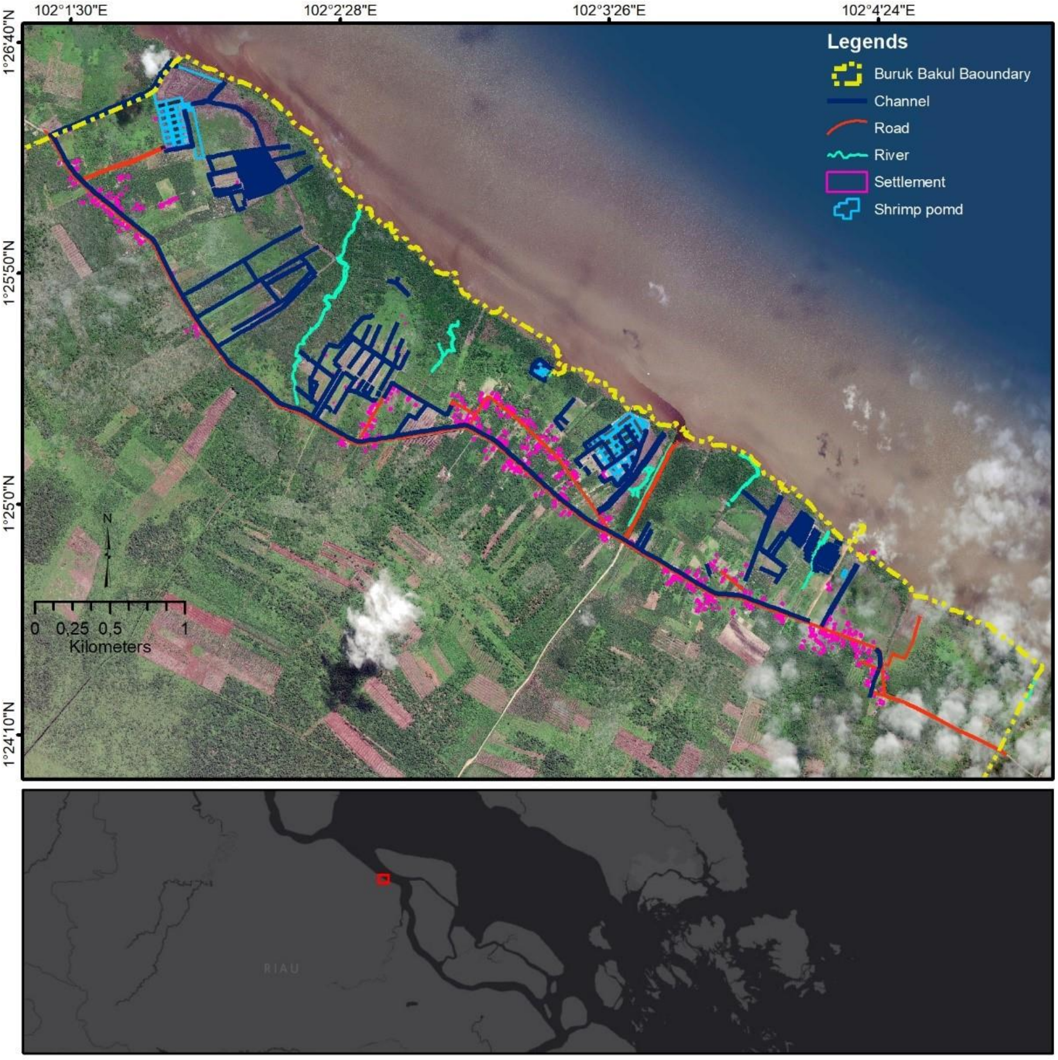

Figure 1. Location of Buruk Bakul village, Riau Province, Indonesia.

Analysis. The analysis begins with mangrove delineation using high-resolution imagery and visual interpretation to identify coastlines, mangrove forests, infrastructure, residential areas, canals, and shrimp ponds. Mangroves are categorized into primary classes: other mangroves and *N. fruticans*. Delineations are updated based on changes in surface objects, particularly in mangrove forests, corresponding to the 2024 Sentinel-2 satellite imagery capture date. The delineation process utilizes polyline features with a snapping tool to avoid undershooting and overshooting errors, transforming these into polygonal shapes for mangrove forest boundaries. Topology construction ensures data quality for each feature.

Mangrove density assessment for 2023 involves analyzing the Normalized Difference Vegetation Index (NDVI) derived from Sentinel-2 Level 2A satellite images. The analysis establishes threshold values of 0.12 (indicating low density) and 1 (indicating high density) as benchmarks. However, due to a lack of corroborating field data, the reporting on mangrove density remains qualitative, ranging from sparse to dense. The study examines the interplay between forest status and spatial patterns of mangroves using overlay (intersect) techniques, integrating spatial pattern data with 2024 mangrove distribution mapping. This analysis incorporates the Riau Province spatial planning data for 2018-2038, which includes forest status and spatial patterns.

The research conducts in-depth interviews with key informants from relevant institutions, including academics from Riau University, representatives of the Peat and Mangrove Restoration Agency, the Riau Provincial Environmental and Forestry Service, and the Regional Forest Area Management Agency Area XIX, to complement the spatial analysis and gather information about sustainable mangrove management opportunities at the study site. The final phase of the study involves synthesizing the spatial analysis results and in-depth interview findings to formulate mangrove management policy recommendations for Buruk Bakul village. This comprehensive approach ensures a thorough understanding of the current mangrove ecosystem status and provides a solid foundation for developing sustainable management strategies.

Results. Mangrove cover in Buruk Bakul Village spans 190.0 hectares, forming a vital ecosystem along the coastline, rivers, and streams leading to the Bengkalis Strait. The mangrove belt thickness varies, reaching up to 1,363 meters in certain areas and between 550 and 814 meters at several points. Mapping identified two cover classes: mixed mangroves (166.1 hectares, 87.4%) and *N. fruticans* species (23.9 hectares, 12.6%). A comparison with 2021 data from the Directorate of Land and Water Conservation reveals a discrepancy of 9.3 hectares, potentially due to differences in data sources and image capture timing. Anthropogenic activities, including infrastructure development and land use changes, have fragmented mangroves at several locations, potentially reducing habitat quality and ecological functions (Figure 2).

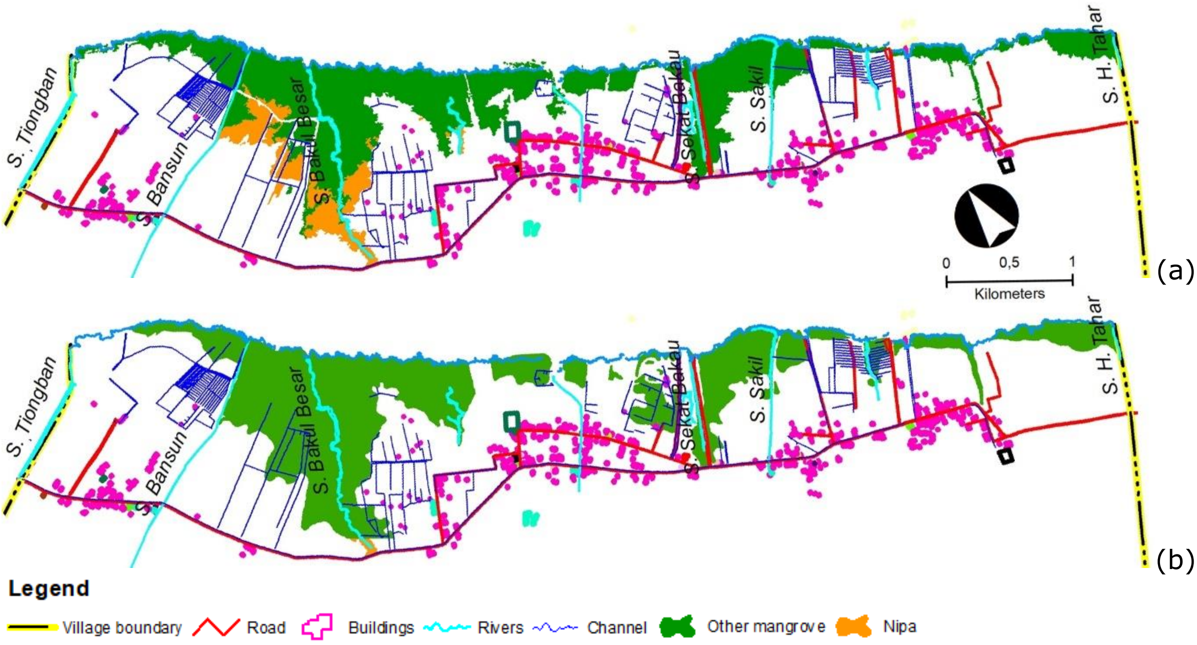

Figure 2. Distribution of mangroves in Buruk Bakul Village. (a) Year 2024, and (b) Year 2021.

NDVI values predominantly indicate medium mangrove density. However, density interpretation remains relative due to varying ranges of minimum to maximum NDVI values. Satellite imagery shows a maximum NDVI value of 0.61. Data from 2021 indicates mangrove density distribution as dense (102.0 hectares, 50.9%), medium (93.7 hectares, 46.8%), and sparse (4.6 hectares, 2.3%) (Direktorat Konservasi Tanah dan Air 2021) (Figure 3).

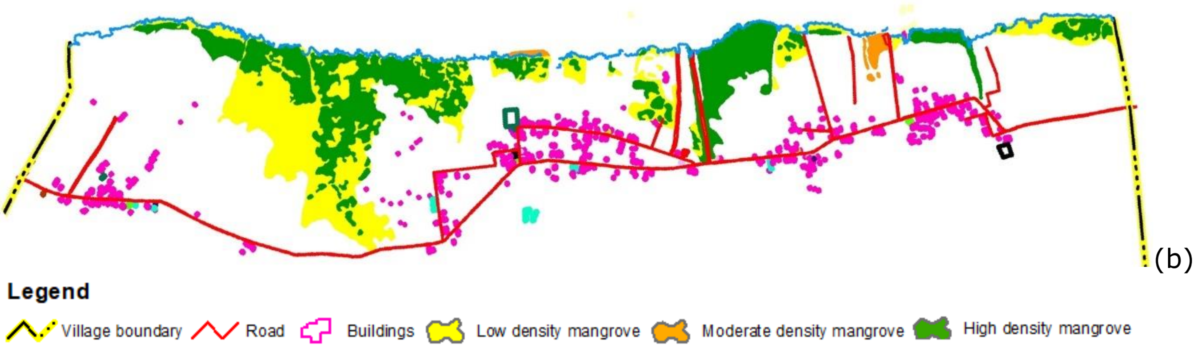

Figure 3. Distribution of mangrove density (a) Data from 2024, (b) Data from the Directorate of Land and Water Conservation (2021).

The Riau Province Spatial Plan classifies all mangroves in Buruk Bakul Village as a non-forest estate (NFE) area. Approximately 32 hectares have been converted into shrimp ponds. The Regional Spatial Plan directs the use of this area for industrial and plantation purposes, with a potential conversion of 189.5 hectares (99.2%) into industrial zones and 1.5 hectares (0.8%) into plantation areas (Figure 4).

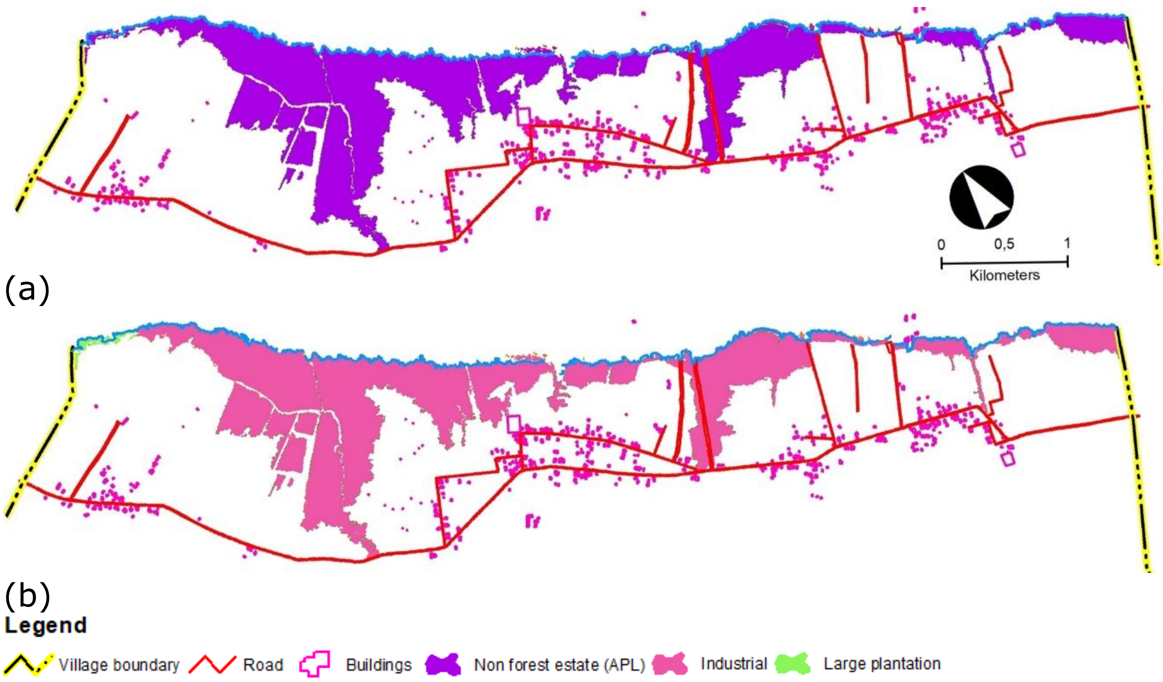

Figure 4. (a) Mangrove forest distribution within Non-Forest Estate (NFE) areas in Buruk Bakul village, and (b) Provincial spatial planning designation of NFE areas for industrial and large-scale plantation development.

Discussion. Mapping results reveal 190 hectares of mangrove cover in Buruk Bakul village within the NFE as per Riau Province's Spatial Plan. This designation threatens mangrove loss due to potential land-use conversion for industrial and plantation purposes aligned with the Regional Spatial Plan. Provincial data indicates a trend of reducing mangrove cover (Oktorini et al 2022). National mangrove rehabilitation efforts from 2015 to 2019 restored only 4,123 hectares, falling short of the 600,000-hectare target (Dharmawan & Pratiwi 2023). These factors necessitate comprehensive study and management to prevent mangrove extinction in Buruk Bakul village.

Mangrove fragmentation significantly deteriorates ecosystem quality in Buruk Bakul village. Activities driving fragmentation include road construction, canalization, water channel normalization, cultivation (oil palm plantations and shrimp farms), and the gradual erosion of forefront mangrove formations (Bryan-Brown et al 2020). This fragmentation and loss reduce the habitat's capacity to provide essential ecosystem services such as erosion prevention, coastline protection, and climate change mitigation through carbon sequestration (Ilman et al 2016; Bryan-Brown et al 2020). Fragmentation also disrupts habitat connectivity, mangrove hydrological processes, and regeneration (Bayraktarov et al 2016). Monitoring mangrove extent and quality is crucial to detect fragmentation and degradation impacts.

Mangrove management in NFE areas presents complex challenges requiring a holistic and synergistic approach amidst overlapping ownership and interests. Most mangrove areas in Indonesia, including Buruk Bakul village, belong to individuals and communities (Mechsan 2012), creating diverse ownership structures that can trigger land-use changes and horizontal conflicts (Kustanti et al 2014). While land ownership in APL mangrove areas complies with regulations like the Minister of Agrarian State Regulation Number 9 of 1999, on-ground realities often present more intricate situations. Mangrove management in NFE areas has gained importance in national initiatives like Indonesia's Forestry and Other Land Use Net Sink 2030, outlined in Government Regulation Number 98 of 2021. This program aims to preserve natural vegetation in Right to Cultivate and NFE areas, including mangroves. Designating NFE mangroves as conservation or protected areas, as done in northern Rupat Island and coastal Indragiri Hilir, represents progressive steps to safeguard biodiversity, historical values, and national culture (DKP Indragiri Hilir 2015; BPSPL 2018). The 'land-use system area' process enables collaborative mangrove conservation management. Community involvement and coordination with village governments become crucial in land ownership inventory and facilitating collaborative management. These efforts find support in regulations like the Minister of Environment and Forestry Regulation Number 23 of 2021, providing a legal foundation for forest and land rehabilitation.

Local regulations play a significant role in supporting mangrove conservation efforts. Enacting local regulations is a strategic step to enhance mangrove ecosystem benefits, maintain functionality, and support sustainable development (Mohamed et al 2023). These regulations strengthen the capacity of relevant parties in mangrove management and emphasize active local community participation in planning and implementation (Febryano et al 2014). Combining strong policies, stakeholder collaboration, and community involvement can make mangrove management in NFE areas more integrated and sustainable. This approach supports biodiversity and sustainable development of mangroves in Indonesia (Sasmito et al 2023), offering a hopeful future for areas like Buruk Bakul Village.

Conclusions. The high-resolution satellite imagery of Buruk Bakul village reveals a significant 9.3-hectare difference in mangrove coverage compared to the 2021 governmental data, highlighting the impact of anthropogenic activities on fragmentation. The study proposes various sustainable management opportunities and stresses the urgent need for conservation measures to counter the decline in mangrove coverage. Active participation in implementing these measures is crucial to preserve the diverse ecological, economic, and social contributions of mangrove ecosystems in Buruk Bakul village.

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Conflict of interest. The authors declare that there is no conflict of interest.

References

Alongi D., 2022 Lateral export and sources of subsurface dissolved carbon and alkalinity in mangroves: revising the blue carbon budget. Journal of Marine Science and Engineering 10(12):1916.

Arifanti V. B., Sidik F., Mulyanto B., Susilowati A., Wahyuni T., Subarno, Yulianti, Yuniarti N., Aminah A., Suita E., Karlina E., Suharti S., Pratiwi, Turjaman M., Hidayat A., Rachmat H. H., Imanuddin R., Yeny I., Darwiati W., Sari N., Hakim S. S., Slamet W. Y., Novita N., 2022 Challenges and strategies for sustainable mangrove management in Indonesia: a review. Forests 13(5):695.

Bayraktarov E., Saunders M. I., Abdullah S., Mills M., Beher J., Possingham H. P., Mumby P. J., Lovelock C. E., 2016 The cost and feasibility of marine coastal restoration. Ecological Applications 26(4):1055-1074.

BPSPL, 2018 [Designation of regional marine conservation area in North Rupat]. Padang, 159 pp. [in Indonesian]

Bryan-Brown D. N., Connolly R. M., Richards D. R., Adame F., Friess D. A., Brown C. J., 2020 Global trends in mangrove forest fragmentation. Scientific Reports 10(1):7117.

Carugati L., Gatto B., Rastelli E., Lo Martire M., Coral C., Greco S., Danovaro R., 2018 Impact of mangrove forests degradation on biodiversity and ecosystem functioning. Scientific Reports 8(1):13298.

Dharmawan I. W. S., Pratiwi, 2023 Implementation of forest-land rehabilitation to support the enhancement of carbon stock on Indonesia’s FOLU net sink 2030 strategy. IOP Conference Series: Earth and Environmental Science 1180(1):012010.

Direktorat Konservasi Tanah dan Air, 2021 [2021 National mangrove map]. Kementerian Lingkungan Hidup dan Kehutanan, Jakarta, 180 pp. [in Indonesian]

DKP Indragiri Hilir, 2015 [Study on the designation of coastal and small islands conservation areas in Indragiri Hilir Regency]. Tembilahan, 212 pp. [in Indonesian]

Eddy S., Ridho M. R., Iskandar I., Mulyana A., 2016 Community-based mangrove forests conservation for sustainable fisheries. Jurnal Silvikultur Tropika 7(3):42-47.

Febryano I. G., Suharjito D., Darusman D., Kusmana C., Hidayat A., 2014 The roles and sustainability of local institutions of mangrove management in Pahawang Island. Jurnal Manajemen Hutan Tropika 20(2):69-76.

García Calva L., Golubov J., Mandujano M. C., Lara-Domínguez L., López-Portillo J., 2019 Assessing Google Earth Pro images for detailed conservation diagnostics of mangrove communities. Journal of Coastal Research 92(SI):33-43.

Goldberg L., Lagomasino D., Thomas N., Fatoyinbo T., 2020 Global declines in human-driven mangrove loss. Global Change Biology 26(10):5844-5855.

Hu Q., Wu W., Xia T., Yu Q., Yang P., Li Z., Song Q., 2013 Exploring the use of Google Earth imagery and object-based methods in land use/cover mapping. Remote Sensing 5(11):6026-6042.

Ilman M., Dargusch P., Dart P., Onrizal, 2016 A historical analysis of the drivers of loss and degradation of Indonesia's mangroves. Land Use Policy 54:448-459.

Islami F. A., Tarigan S. D., Wahjunie E. D., Dasanto B. D., 2022 Accuracy assessment of land use change analysis using Google Earth in Sadar Watershed Mojokerto Regency. IOP Conference Series: Earth and Environmental Science 950(1):012091.

Jhonnerie R., Prianto E., Oktorini Y., 2007 [Detection of mangrove forest area changes using remote sensing and geographic information system in Dumai City, Riau Province]. Torani 17(2):159-169. [in Indonesian]

Jhonnerie R., Siregar V. P., Nababan B., Prasetyo L. B., Wouthuyzen S., 2014 [Mangrove coverage change detection using Landsat imageries based on hybrid classification in Kembung River, Bengkalis Island, Riau Province]. Jurnal Ilmu dan Teknologi Kelautan Tropis 6(2):491-506. [in Indonesian]

Jhonnerie R., Siregar V. P., Nababan B., Prasetyo L. B., Wouthuyzen S., 2015 Random forest classification for mangrove land cover mapping using Landsat 5 TM and Alos Palsar imageries. Procedia Environmental Sciences 24:215-221.

Kanniah K. D., Ping H. L., Lau A., 2013 Mapping mangrove species using Worldview-2 satellite data. 34th Asian Conference on Remote Sensing 2013, ACRS 2013 3:2668-2674.
Kelleway J. J., Cavanaugh K., Rogers K., Feller I. C., Ens E., Doughty C., Saintilan N., 2017 Review of the ecosystem service implications of mangrove encroachment into salt marshes. Global Change Biology 23(10):3967-3983.
Kochoni B. I., Avakoudjo H. G. G., Kamelan T. M., Sinsin C. B. L., Kouamelan E. P., 2023 Contribution of mangroves ecosystems to coastal communities' resilience towards climate change: a case study in southern Cote d'Ivoire. GeoJournal 88:3935-3951.
Kustanti A., Nugroho B., Nurrochmat D. R., Okimoto Y., 2014 [Evolution of property rights in mangrove forest ecosystem management at Lampung Mangrove Centre]. Risalah Kebijakan Pertanian dan Lingkungan 1(3):143-158. [in Indonesian]
Li Z., Shen H., Weng Q., Zhang Y., Dou P., Zhang L., 2022 Cloud and cloud shadow detection for optical satellite imagery: features, algorithms, validation, and prospects. ISPRS Journal of Photogrammetry and Remote Sensing 188:89-108.
Mechsan S., 2012 [Land ownership status in coastal areas of Bandar Lampung City]. Fiat Justitia Jurnal Ilmu Hukum 5(2):228-235. [in Indonesian]
Mohamed M. K., Adam E., Jackson C. M., 2023, Policy review and regulatory challenges and strategies for the sustainable mangrove management in Zanzibar. Sustainability 15(2):1557.
Mukherji S., Imchen M., Mondal S., Bhattacharyya A., Siddhardha B., Kumavath R., Ghosh A., 2022 Anthropogenic impact accelerates antibiotic resistome diversity in the mangrove sediment of Indian Sundarban. Chemosphere 309:136806.
Nagelkerken I., Blaber S. J. M., Bouillon S., Green P., Haywood M., Kirton L. G., Meynecke J. O., Pawlik J., Penrose H. M., Sasekumar A., Somerfield P. J., 2008 The habitat function of mangroves for terrestrial and marine fauna: a review. Aquatic Botany 89(2):155-185.
Neukermans G., Dahdouh-Guebas F., Kairo J. G., Koedam N., 2008 Mangrove species and stand mapping in Gazi bay (Kenya) using Quickbird satellite imagery. Journal of Spatial Science 53(1):75-86.
Nguyen H. Q., Pham T. T. N., Le T. V. H., Dao V. T., Quinn C., Carrie R., Stringer L., 2019 Spatial planning influences mangrove forest development in Kim Son District of Ninh Binh Province. FIG Working Week 2019 Hanoi, pp. 1-20.
Oktorini Y., Jhonnerie R., Siregar H. S., Miswadi, 2013 Separabilty of mangrove landcover by using RapidEye satellte magery. The 2nd International Seminar of Fisheries and Marine, Pekanbaru, pp. 147-153.
Oktorini Y., Prianto E., Darlis V. V., Rahmatdillah, Miswadi, Jhonnerie R., 2022 [Riau mangroves: distribution and status of changes]. Dinamika Lingkungan Indonesia 9(1):50-57. [in Indonesian]
Raju R. D., Arockiasamy M., 2022 Coastal protection using integration of mangroves with floating barges: an innovative concept. Journal of Marine Science and Engineering 10(5):612.
Rudianto R., Bengen D. G., Kurniawan F., 2020 Causes and effects of mangrove ecosystem damage on carbon stocks and absorption in East Java, Indonesia. Sustainability 12(24):10319.
Sasmito S. D., Basyuni M., Kridalaksana A., Saragi-Sasmito M. F., Lovelock C. E., Murdiyarso D., 2023 Challenges and opportunities for achieving sustainable development goals through restoration of Indonesia’s mangroves. Nature Ecology and Evolution 7(1): 62-70.
Seygita V., Sulistiono, Kusmana C., Yulianto G., 2022 Mangroves and the sustainability of longtail shad fish (*Tenualosa macrura*) in Riau Province water, Indonesia. International Journal on Advanced Science, Engineering and Information Technology 12(5):1744-1755.
Wang L., Sousa W. P., Gong P., Biging G. S., 2004 Comparison of IKONOS and QuickBird images for mapping mangrove species on the Caribbean coast of Panama. Remote Sensing of Environment 91(3-4):432-440.

Yllano O. B., Summers J. K., 2023 Mangrove biology, ecosystem, and conservation. IntechOpen, Rijeka, 146 pp.

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