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Review Paper

Mangrove in Biodiversitas: A Systematic Review of Biodiversity, Blue Carbon, and Ecosystem Services in Southeast Asia (2020-2025)

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ABSTRACT

Mangrove ecosystems are socio-ecological systems that sustain high biodiversity, sequester blue carbon, and deliver services essential for coastal resilience and livelihoods. This systematic review synthesizes mangrove articles published in Biodiversitas (2020-2025), integrating evidence across biodiversity/bioindicators, blue carbon stocks and drivers, and ecosystem services with governance outcomes. Following PRISMA-guided screening and standardized extraction, 57 empirical studies were analyzed for spatial-methodological trends and reported linkages among ecological condition, carbon pools, and human benefits. Across sites, intact and structurally complex mangroves consistently showed higher biomass and soil organic carbon, while bioindicator groups (benthic macrofauna, birds, gastropods, and microbial communities) reliably tracked environmental gradients and anthropogenic pressure. Socio-ecological studies indicated that community-based and co-managed arrangements are most associated with durable ecological integrity and livelihood co-benefits, whereas degraded, urban-adjacent, and intensively managed systems tended to show reduced biodiversity, lower carbon stocks, and weakened service provision. Key gaps include limited functional diversity metrics, inconsistent carbon accounting (especially SOC depth conventions), and scarce longitudinal socio-economic monitoring. Overall, the evidence supports integrated research and policy frameworks that jointly advance biodiversity conservation, climate mitigation, and sustainable development in Southeast Asia.

Keywords: *mangroves; biodiversity; blue carbon; ecosystem services; socio-ecological systems; Southeast Asia; conservation governance*

INTRODUCTION

Mangrove ecosystems are critical coastal habitats that support unique biodiversity, protect shorelines, and store large amounts of blue carbon. In Southeast Asia-the world's largest mangrove hotspot-these ecosystems underpin nursery habitats for fisheries and provide refugia for diverse taxa (Giri et al., 2010; Wainwright et al., 2022; Dencer-Brown et al., 2018). Through dense root networks, mangroves attenuate waves, stabilize sediments, and reduce storm impacts, functions that are increasingly vital under climate change scenarios (Mao et al., 2021; Tian et al., 2023). Furthermore, because mangrove soils and biomass store exceptionally high carbon densities, their conservation and restoration are widely recognized as effective nature-based climate mitigation strategies (Kauffman et al., 2020; Sasmito et al., 2019; Sharma et al., 2023).

Beyond biodiversity, mangroves deliver critical regulating services such as storm-surge buffering and erosion control. These services are vital for safeguarding human settlements, infrastructure, and livelihoods, particularly in densely populated coastal zones across Indonesia, Malaysia, the Philippines, and Thailand. A growing body of evidence highlights the remarkable blue carbon potential of these ecosystems. Their unique ecological position at the land–sea interface enables mangroves to store disproportionately large amounts of carbon in both biomass and soil compared to other coastal ecosystems. Studies suggest that mangrove ecosystems can accumulate up to 949 Mg C/ha, positioning them among the world's most efficient natural carbon sinks (Kauffman et al., 2020; Sasmito et al., 2019).

Between 2020 and 2025, scientific publications focusing on mangrove biodiversity, blue carbon, and ecosystem services have surged, particularly within the Indo-Pacific region. This trend mirrors a growing awareness of the multifaceted ecological roles of mangroves and aligns with broader scientific discussions on nature-based solutions. Recent literature emphasizes the interdependence between mangrove health, biodiversity, and carbon storage capacity, demonstrating that species richness, stand structure, and ecosystem integrity strongly influence the magnitude of carbon sequestration (Sharma et al., 2023; Dencer-Brown et al., 2018). Moreover, advances in remote sensing and ecological modeling have enabled more precise assessments of mangrove cover, health, and biomass (Gandhi & Jones, 2019).

However, despite this growing body of research, mangrove science remains fragmented. Biodiversity, carbon sequestration, and socio-economic dimensions are often examined in isolation, with few studies integrating these elements holistically. Research tends to focus either on ecological assessments (Gerona-Daga & Salmo, 2022) or on carbon accounting, frequently neglecting the socio-economic implications of conservation (Sasmito et al., 2019). Meanwhile, studies addressing livelihoods and governance remain underrepresented or detached from ecological analyses (Kundu et al., 2025; Gerona-Daga & Salmo, 2022). This thematic fragmentation limits our understanding of ecosystem multifunctionality and risks undermining the design of comprehensive conservation policies.

This systematic review addresses these challenges by synthesizing mangrove research published in *Biodiversitas* between 2020 and 2025. The objectives are threefold: (i) to map the evidence on mangrove biodiversity, blue carbon, and ecosystem services; (ii) to identify spatial, thematic, and methodological patterns; and (iii) to construct an integrated framework that elucidates relationships among ecological functions, carbon dynamics, and socio-economic outcomes.

MATERIALS AND METHODS

Study Design

This systematic literature review (SLR) was designed and implemented following internationally recognized best-practice guidelines for evidence synthesis in environmental sciences. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework served as the primary reporting guideline to ensure methodological rigor, transparency, and reproducibility (Liberati et al., 2009; Page et al., 2021). The review protocol was developed based on principles outlined by Breen et al. (2023), emphasizing explicit formulation of research questions and predefined eligibility criteria.

Figure 1 illustrates the sequential process used to identify, screen, and select eligible studies: (i) identification through database searches, (ii) removal of duplicates, (iii) title–abstract screening, (iv) full-text eligibility assessment, and (v) inclusion in data synthesis.

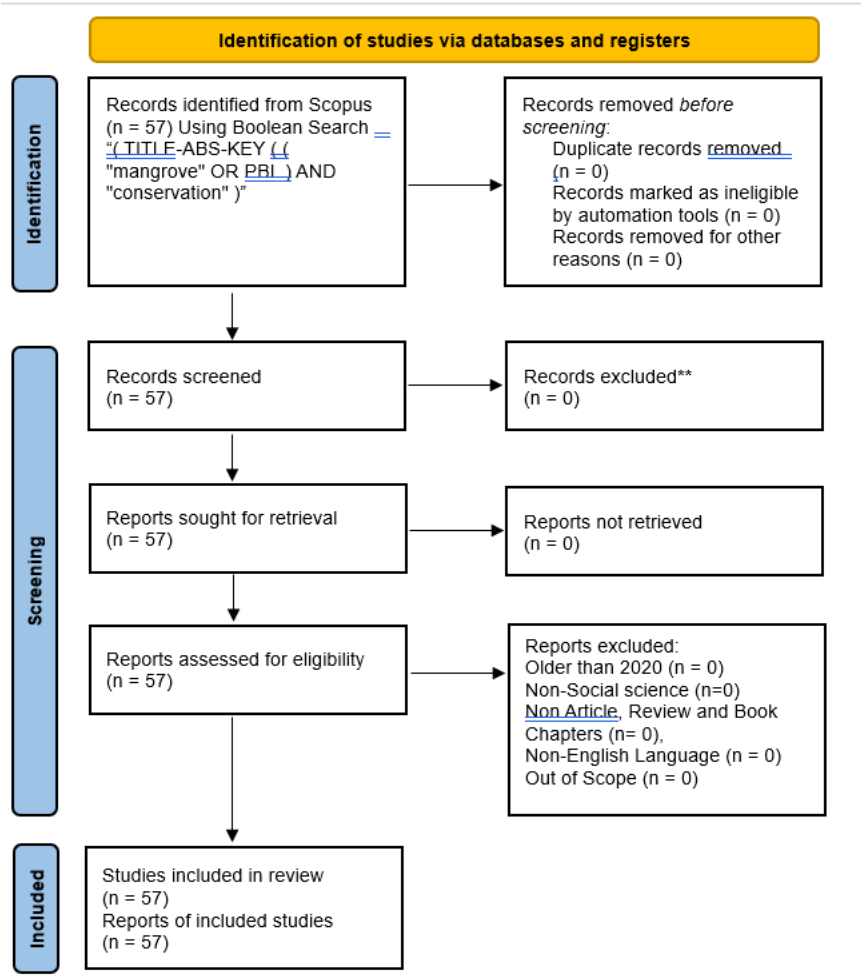

Figure 1. PRISMA Flow Diagram.

Search Strategy and Data Sources

A systematic search strategy was developed to gather all relevant studies published between 2020 and 2025 in *Biodiversitas* that addressed mangrove ecosystems in Southeast Asia. Three primary data sources were consulted: (i) the *Biodiversitas* journal portal, which served as the core repository; (ii) Scopus, used to confirm indexing accuracy; and (iii) Google Scholar, employed as a complementary source.

The search strategy combined Boolean operators and keyword strings derived from the conceptual components of mangrove science. Core keywords included: "mangrove", "blue carbon", "ecosystem services", "biodiversity", "carbon stock", "ecotourism", "valuation", "restoration", and "species diversity". All searches were limited to the period 2020–2025.

Inclusion and Exclusion Criteria

Eligibility criteria were predefined in accordance with SLR methodological standards (Breen et al., 2023):

- Inclusion Criteria: (1) Peer-reviewed empirical research published in *Biodiversitas* (2020–2025); (2) Studies conducted within Southeast Asia (Indonesia, Malaysia, Philippines, Thailand, etc.); (3) Articles addressing at least one of the three pillars: biodiversity, blue carbon, or ecosystem services/socio-ecological outcomes.
- Exclusion Criteria**:** (1) Studies not involving mangrove ecosystems; (2) Publications outside Southeast Asia; (3) Article types lacking empirical data (e.g., reviews, editorials).

Screening and Data Extraction

The screening process followed a two-stage procedure: title–abstract screening followed by full-text eligibility assessment. A structured extraction template was used to capture: bibliographic information, study location, ecosystem type (natural, restored, degraded), focal taxa, indicators (e.g., Shannon index, AGB, SOC), and management context.

Quality Appraisal

Study quality was appraised using a hybrid PRISMA-informed approach drawing on JBI and CASP checklists (Atkinson et al., 2014; Freischlager et al., 2022). Studies were evaluated based on clarity of objectives, transparency of methods, appropriateness of sampling design, and rigor of analytical methods.

THEORETICAL FRAMEWORK

Mangroves as Multifunctional Social-Ecological Systems (SES)

Mangrove ecosystems are increasingly conceptualized as multifunctional social-ecological systems (SES). The SES framework provides an integrative lens through which mangroves are understood as systems where ecological structure, environmental drivers, and socio-economic activities mutually influence one another (Hagger et al., 2022; Sarker et al., 2025). This perspective emphasizes interactions among resource systems (mangrove forests), resource users (coastal communities), and governance systems. For example, Hagger et al. (2022) illustrate that enhanced market access often leads to mangrove degradation due to land conversion, highlighting the necessity for management that integrates ecological sustainability with socio-economic realities.

Biodiversity–Function–Service Relationships

The connections between biodiversity, ecosystem functioning, and ecosystem services lie at the heart of mangrove ecology. Empirical studies demonstrate that higher species richness enhances functional attributes such as nutrient cycling, productivity, and resilience (Balvanera et al., 2006). In mangrove settings, diverse assemblages contribute to system stability by occupying complementary ecological niches. Egoh et al. (2009) show that species-rich coastal ecosystems exhibit greater productivity. Consequently, biodiversity underpins provisioning services (fisheries), regulating services (carbon sequestration, coastal protection), and cultural services (Grizzetti et al., 2019; Graves et al., 2017).

Blue Carbon Accounting Frameworks

Mangroves are among the most carbon-rich ecosystems globally. Their carbon storage capacities are analyzed using standardized frameworks, primarily the IPCC Guidelines (2006), which outline methods to quantify carbon in above-ground biomass (AGB), below-ground biomass (BGB), and soil organic carbon (SOC). Allometric equations relate measurable tree parameters (e.g., DBH) to biomass (Indrayani et al., 2021; Akhrianti et al., 2024), while remote sensing provides spatially explicit data on canopy structure (Hu et al., 2020). SOC typically constitutes the largest carbon pool, often accounting for up to 78% of total mangrove carbon stocks (Hidayati et al., 2023).

Conceptual Framework for the Review

Consistent with the SLR framework, this study adopts an integrated conceptual model connecting ecological and socio-economic dimensions of mangrove ecosystems. This model synthesizes elements from SES, DPSIR, resilience theory, and blue carbon accounting to analyze ecosystem multifunctionality.

Components of the Conceptual Model

1. Drivers:

Land-use change (e.g., aquaculture, agriculture)
Urbanization and infrastructure development
Climate change and sea-level rise
Market pressures and governance structures

2. Pressures:

Deforestation, degradation, pollution, hydrological alteration

3. State Variables:

Biodiversity attributes (species composition, structural complexity)
Carbon stocks (AGC, BGC, SOC)
Habitat condition and ecological connectivity

4. Ecosystem Services:

Regulating (carbon sequestration, coastal protection)
Provisioning (fisheries, timber)
Cultural (tourism, heritage values)
Supporting (nursery habitats, nutrient cycling)

5. Socio-Economic Outcomes:

Livelihood security
Food availability and fisheries productivity
Ecotourism opportunities
Policy development and governance effectiveness

RESULTS

Overview of Mangrove Studies (2020–2025)

Research on mangrove ecosystems published in *Biodiversitas* between 2020 and 2025 exhibits clear temporal, spatial, and methodological patterns. Southeast Asia remains the global epicenter of mangrove research, with a strong concentration of studies in Indonesia, Malaysia, and the Philippines. This geographical focus is driven by the region's extensive mangrove cover and high socio-economic dependence on these ecosystems (Giri et al., 2010; Lovelock et al., 2015).

Methodologically, the studies employ diverse approaches ranging from traditional field surveys to advanced remote sensing and socio-economic valuation. While field surveys remain the backbone of biodiversity assessments, remote sensing is increasingly utilized for carbon stock estimation and land cover monitoring. Table 1 provides an overview of the key studies reviewed, highlighting their location, design, and primary thematic focus.

Table 1. Overview of Mangrove Studies in *Biodiversitas* (2020–2025)

Study ID / Citation	Country & Site	Study Design & Methods	Primary Theme	Secondary Focus	Data Type & Scale
Ramli et al. (2025)	Malaysia – Pulau Tuba, Langkawi	Field survey (meiofauna sampling)	Biodiversity	Ecosystem health	Local, snapshot
Thoha et al. (2025)	Indonesia – North Sumatra	Remote sensing (Sentinel imagery)	Blue Carbon	Spatial modelling	Local–regional

Manan et al. (2025)	Indonesia – Wakatobi	Field surveys; carbon estimation	Mixed	Economic valuation	Local
Latuconsina et al. (2025)	Indonesia – Semi-enclosed bay	Fish composition surveys	Biodiversity	Habitat comparison	Local
Balatero et al. (2025)	Philippines	eDNA metabarcoding	Biodiversity	Conservation	Local
Samsuri et al. (2025)	Indonesia – North Sumatra	Remote sensing + socio-ecology	Ecosystem Services	Governance	Local
Dharmayasa et al. (2025)	Indonesia – Bali	Vegetation surveys	Biodiversity	Soil gradients	Local
Juliantari et al. (2025)	Indonesia	Microbial sampling	Biodiversity	Decomposition	Local
Rosales et al. (2025)	Philippines – Cebu	Economic valuation	Ecosystem Services	Conservation	Local
Yulianto et al. (2025)	Indonesia – East Java	Post-restoration surveys	Environmental	Succession	Local, longitudinal
Noer et al. (2025)	Indonesia – Bunaken	Insect surveys	Biodiversity	Pollinators	Local
Carong et al. (2024)	Philippines	Biomass + carbon sampling	Blue Carbon	Restoration	Local
Fatmawati et al. (2024)	Indonesia – Papua	Biodiversity surveys	Biodiversity	Conservation	Local
Hilmi et al. (2024)	Indonesia – Ujung Pangkah	Biomass + SOC	Blue Carbon	Land use	Local
Huda et al. (2024)	Philippines – Cebu	Vegetation surveys	Biodiversity	Disturbance	Local
Makkawaru et al. (2024)	Indonesia – Gorontalo	Vegetation surveys	Biodiversity	Conservation	Local
Marasabessy et al. (2024)	Indonesia – Seram	Socio-ecological surveys	Ecosystem Services	Governance	Local
Santoso et al. (2024)	Indonesia – Timor	Remote sensing	Environmental	Land cover	Regional
Anggraeni et al. (2024)	Indonesia – West Papua	Vegetation mapping	Biodiversity	Management	Local
Prihantono et al. (2024)	Malaysia – Johor	Bird surveys	Biodiversity	Conservation	Local
Nugraha et al. (2023)	Indonesia – East Java	Ecotourism assessment	Ecosystem Services	Tourism	Local
Salman et al. (2023)	Indonesia – Rawa Aopa	Carbon inventory	Blue Carbon	Conservation	Local

Biodiversity Metrics and Bioindicators

Biodiversity assessments in the reviewed studies consistently demonstrate that mangrove ecological structure is highly sensitive to environmental gradients and anthropogenic disturbance. Vegetation studies (e.g., Dharmayasa et al., 2025; Fatimah et al., 2024) report higher species richness and structural complexity in natural, intact sites compared to degraded or urban-adjacent areas.

Faunal diversity serves as a robust indicator of ecosystem health. The review identified several key bioindicator groups, including benthic macrofauna, birds, gastropods, and microbial communities. For instance, Latuconsina et al. (2025) found reduced fish richness in disturbed habitat mosaics, while Astiani et al. (2024) reported high avifaunal diversity in protected areas. Table 2 summarizes the biodiversity metrics and key findings regarding bioindicators across the reviewed studies.

Table 2. Biodiversity Metrics and Bioindicators in Mangrove Studies (2020–2025)

Study ID / Citation	Taxa / Biotic Group	Biodiversity / Indicator Metrics	Environmental Gradient / Condition	Key Findings on Biodiversity Patterns	Implications for Monitoring & Management
Ramli et al. (2025)	Meiofauna	Richness, abundance	Monsoonal variation	Assemblage shifts under seasonal gradients	Seasonal monitoring of meiofauna recommended
Dharmayasa et al. (2025)	Vegetation	Richness, density, H'	Soil texture gradient	Species turnover across soil types	Soil-based zoning for restoration planning
Fatmawati et al. (2024)	Vegetation	Richness, H'	Natural forest	High species richness in intact forests	Priority conservation zones identified
Hilmi et al. (2024)	Vegetation	Biomass, structure	Land-use gradient	Biomass declines in disturbed sites	Integration with carbon monitoring
Latuconsina et al. (2025)	Fish	Species composition	Habitat mosaic	Reduced richness in disturbed mosaics	Habitat protection for fisheries
Prihantono et al. (2024)	Birds	Richness, H'	Protected area	High avifaunal diversity	Long-term bird monitoring for PA management
Nazhifah et al. (2024)	Gastropods	Richness, D	Disturbance gradient	Lowest diversity in degraded zones	Use gastropods as disturbance indicators
Noer et al. (2025)	Insects	Species composition	Protected area	High pollinator abundance	Indicator for vegetation condition

Faradilla et al. (2022)	Crustaceans	Richness	Salinity gradient	Assemblage shifts across salinity	Salinity-sensitive monitoring programs
Juliantari et al. (2025)	Microbes	Microbial identities	Leaf litter gradients	Indicator of nutrient cycling	Bioindicator for decomposition processes
Sudirman et al. (2020)	Gastropods	Richness, H'	Natural vs disturbed	Strong sensitivity to disturbance	Early detection of degradation

Blue Carbon Assessments

Blue carbon assessments confirm the critical role of mangroves in climate mitigation. The findings strongly support the hypothesis that natural mangroves store significantly more carbon than degraded or converted systems. Studies employing allometric equations and soil coring (e.g., Manan et al., 2025; Wintah et al., 2023) consistently found higher AGB and SOC in intact forests.

Restoration initiatives show variable success in recovering carbon stocks. While some sites exhibit increasing biomass (Friess et al., 2016), others lag due to poor hydrological connectivity. The integration of remote sensing (Thoha et al., 2025) has improved the scalability of carbon estimates, although field validation remains essential. Table 3 presents a synthesis of the blue carbon assessments.

Table 3. Blue Carbon Assessments in Mangrove Studies (2020–2025)

Study ID / Citation	Carbon Pools Measured	Methods & Tools	Land-Use / Management Context	Reported Carbon Stocks / Ranges	Key Drivers / Explanatory Variables
Thoha et al. (2025)	AGB	Remote sensing (Sentinel), field calibration	Coastal mangroves	Not reported	Canopy density, land-use intensity
Manan et al. (2025)	AGB, BGB, SOC	Field plots, allometry, soil cores	Protected biosphere reserve	Not reported	Stand age, species composition
Carong et al. (2024)	AGB, SOC	Field plots, soil sampling	Restored ponds vs natural	Not reported	Restoration age, hydrology
Agustriani et al. (2024)	SOC	Soil coring	Estuarine mangrove	Not reported	Sediment type, disturbance
Hilmi et al. (2024)	AGB, SOC	Plot-based, soil cores	Protected vs disturbed	Not reported	Land-use gradient
Syari et al. (2022)	Total C (AGB+BGB+SOC)	Plots + allometry	Silvofishery ponds	Not reported	Management practices
Susiati et al. (2021)	AGB	Plot sampling	Natural forests	Not reported	Stand structure
Salman et al. (2023)	Total ecosystem C	Plots + soil sampling	National park	Not reported	Protection status

Sari et al. (2020)	Ecosystem C	Field sampling	Mixed-use	Not reported	Species composition

Community-Based Governance and Socio-Ecological Outcomes

The review highlights governance as a decisive factor in sustainable mangrove management. Community-based and co-managed arrangements are consistently linked to better ecological and socio-economic outcomes. Studies such as Nugraha et al. (2023) and Latuconsina et al. (2025) demonstrate that when communities are actively involved in management and benefit-sharing (e.g., through ecotourism), both biodiversity and livelihoods improve. Conversely, top-down or intensive management systems (e.g., silvofishery ponds) often prioritize short-term provisioning services at the expense of long-term ecological resilience (Harefa et al., 2021).

DISCUSSION

The systematic review of *Biodiversitas* publications (2020–2025) reveals a dynamic research landscape that increasingly integrates ecological and socio-economic dimensions. The findings confirm the theoretical proposition that biodiversity, carbon storage, and ecosystem services are inextricably linked. Intact mangrove forests with high species richness and structural complexity consistently support higher carbon stocks and deliver more robust regulating services (Wintah et al., 2023; Manan et al., 2025).

However, the review also identifies significant divergences and gaps. There is a notable inconsistency in carbon accounting methodologies, particularly regarding the depth of soil sampling and the choice of allometric equations. This variability complicates cross-site comparisons and underscores the need for standardized protocols aligned with IPCC guidelines (O'Connor et al., 2020). Furthermore, while biodiversity assessments are abundant, they predominantly rely on taxonomic indices; functional diversity metrics remain scarce, limiting our understanding of ecosystem resilience (Chen et al., 2023).

Governance arrangements emerge as a critical mediator of socio-ecological outcomes. The success of community-based models suggests that inclusive governance is essential for resolving trade-offs between conservation and development. Future research must therefore prioritize interdisciplinary approaches that combine robust ecological monitoring with longitudinal socio-economic analysis.

CONCLUSION

This study synthesized mangrove research published in *Biodiversitas* between 2020 and 2025, providing a comprehensive overview of the state of knowledge in Southeast Asia. The review confirms that higher ecological integrity is consistently associated with larger blue carbon stocks and enhanced ecosystem service delivery.

Key conclusions include:

Biodiversity and Function: Intact, species-rich mangroves support superior ecosystem functions compared to degraded or monoculture systems.

Blue Carbon: Natural mangroves are critical carbon sinks, but stocks are highly sensitive to land-use change and hydrological disruption.

Governance: Community-based management offers the most promising pathway for sustaining mangrove multifunctionality.

Future Directions: Researchers should prioritize the adoption of functional diversity metrics, standardized carbon accounting protocols, and longitudinal socio-economic monitoring to inform evidence-based policy and management.

Declaration by Authors

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REFERENCES

1. Abson, D. J., & Termansen, M. (2010). Valuing Ecosystem Services in Terms of Ecological Risks and Returns. Conservation Biology, 25(2), 250–258. https://doi.org/10.1111/j.1523-1739.2010.01623.x
2. Aburto-Oropeza, O., Ezcurra, E., Danemann, G. D., Valdez, V. C., Murray, J., & Sala, E. (2008). Mangroves in the Gulf of California Increase Fishery Yields. Proceedings of the National Academy of Sciences, 105(30), 10456–10459. https://doi.org/10.1073/pnas.0804601105
3. Akhrianti, I., Ningsih, T. S., Wahidin, L. O., Hudatwi, M., Nurhadini, & Gustomi, A. (2024). Estimation of Carbon Stock, Biomass and CO2 Sequestration at Mangrove Forest in Batu Rusa River and Serata Pasir Padi, Bangka Island. IOP Conference Series Earth and Environmental Science, 1419(1), 012042. https://doi.org/10.1088/1755-1315/1419/1/012042
4. Atkinson, K. M., Koenka, A. C., Sanchez, C. E., Moshontz, H., & Cooper, H. (2014). Reporting Standards for Literature Searches and Report Inclusion Criteria: Making Research Syntheses More Transparent and Easy to Replicate. Research Synthesis Methods, 6(1), 87–95. https://doi.org/10.1002/jrsm.1127
5. Balvanera, P., Pfisterer, A. B., Buchmann, N., et al. (2006). Quantifying the Evidence for Biodiversity Effects on Ecosystem Functioning and Services. Ecology Letters, 9(10), 1146–1156. https://doi.org/10.1111/j.1461-0248.2006.00963.x
6. Bennett, E. M., Peterson, G., & Gordon, L. (2009). Understanding Relationships Among Multiple Ecosystem Services. Ecology Letters, 12(12), 1394–1404. https://doi.org/10.1111/j.1461-0248.2009.01387.x
7. Bhowmik, A. K., Padmanaban, R., Cabral, P., & Romeiras, M. M. (2022). Global Mangrove Deforestation and Its Interacting Social-Ecological Drivers: A Systematic Review and Synthesis. Sustainability, 14(8), 4433. https://doi.org/10.3390/su14084433
8. Breen, K., Montes, M., Wu, H., & Lai, B. S. (2023). College Students and Environmental Disasters: A Review of the Literature. Social Sciences, 13(1), 8. https://doi.org/10.3390/socsci13010008
9. Bunting, P., Rosenqvist, Å., Lucas, R., et al. (2018). The Global Mangrove Watch-A New 2010 Global Baseline of Mangrove Extent. Remote Sensing, 10(10), 1669. https://doi.org/10.3390/rs10101669
10. Chen, G., Gu, X., Capinha, C., et al. (2023). Large-scale Changes in Macrobenthic Biodiversity Driven by Mangrove Afforestation. Journal of Applied Ecology, 60(10), 2066–2078. https://doi.org/10.1111/1365-2664.14462
11. Dencer-Brown, A., Alfaro, A. C., Milne, S., & Perrott, J. K. (2018). A Review on Biodiversity, Ecosystem Services, and Perceptions of New Zealand's Mangroves: Can We Make Informed Decisions About Their Removal? Resources, 7(1), 23. https://doi.org/10.3390/resources7010023
12. Egoh, B. N., Reyers, B., Rouget, M., Bode, M., & Richardson, D. M. (2009). Spatial Congruence Between Biodiversity and Ecosystem Services in South Africa. Biological Conservation, 142(3), 553–562. https://doi.org/10.1016/j.biocon.2008.11.009
13. Fabricius, C., Folke, C., Cundill, G., & Schultz, L. (2007). Powerless Spectators, Coping Actors, and Adaptive Co-Managers: A Synthesis of the Role of Communities in Ecosystem Management. Ecology and Society, 12(1). https://doi.org/10.5751/es-02072-120129
14. Freischlager, L., Siegel, M., Friedrich, A., & Zemp, M. (2022). Longitudinal Psychological Family Studies in Austria: A Scoping Review. Journal of Family Issues, 44(9), 2355–2378. https://doi.org/10.1177/0192513x221092026
15. Friess, D. A., Thompson, B. S., Brown, B., et al. (2016). Policy Challenges and Approaches for the Conservation of Mangrove Forests in Southeast Asia.

Conservation Biology, 30(5), 933–949. https://doi.org/10.1111/cobi.12784
16. Gandhi, S., & Jones, T. (2019). Identifying Mangrove Deforestation Hotspots in South Asia, Southeast Asia and Asia-Pacific. Remote Sensing, 11(6), 728. https://doi.org/10.3390/rs11060728
17. Gerona-Daga, M. E., & Salmo, S. G. (2022). A Systematic Review of Mangrove Restoration Studies in Southeast Asia: Challenges and Opportunities for the United Nation's Decade on Ecosystem Restoration. Frontiers in Marine Science, 9. https://doi.org/10.3389/fmars.2022.987737
18. Getzner, M., & Islam, M. S. (2020). Ecosystem Services of Mangrove Forests: Results of a Meta-Analysis of Economic Values. International Journal of Environmental Research and Public Health, 17(16), 5830. https://doi.org/10.3390/ijerph17165830
19. Giri, C., Ochieng, E. O., Tieszen, L. L., et al. (2010). Status and Distribution of Mangrove Forests of the World Using Earth Observation Satellite Data. Global Ecology and Biogeography, 20(1), 154–159. https://doi.org/10.1111/j.1466-8238.2010.00584.x
20. Graves, R. A., Pearson, S. M., & Turner, M. G. (2017). Species Richness Alone Does Not Predict Cultural Ecosystem Service Value. Proceedings of the National Academy of Sciences, 114(14), 3774–3779. https://doi.org/10.1073/pnas.1701370114
21. Grizzetti, B., Liquete, C., Pistocchi, A., et al. (2019). Relationship Between Ecological Condition and Ecosystem Services in European Rivers, Lakes and Coastal Waters. The Science of the Total Environment, 671, 452–465. https://doi.org/10.1016/j.scitotenv.2019.03.155
22. Hagger, V., Worthington, T. A., Lovelock, C. E., et al. (2022). Drivers of Global Mangrove Loss and Gain in Social-Ecological Systems. Nature Communications, 13(1). https://doi.org/10.1038/s41467-022-33962-x
23. Hidayati, J. R., Alviana, D., Anggraini, R., et al. (2023). Estimation of Potential Carbon Stocks in Mangrove Ecosystems in the Riau Islands. Bio Web of Conferences, 70, 02013. https://doi.org/10.1051/bioconf/20237002013
24. Himes-Cornell, A., Grose, S. O., & Pendleton, L. H. (2018). Mangrove Ecosystem Service Values and Methodological Approaches to Valuation: Where Do We Stand? Frontiers in Marine Science, 5. https://doi.org/10.3389/fmars.2018.00376
25. Hu, T., Zhang, Y., Su, Y., Zheng, Y., Lin, G., & Guo, Q. (2020). Mapping the Global Mangrove Forest Aboveground Biomass Using Multisource Remote Sensing Data. Remote Sensing, 12(10), 1690. https://doi.org/10.3390/rs12101690
26. Indrayani, E., Kalor, J. D., Warpur, M., & Hamuna, B. (2021). Using Allometric Equations to Estimate Mangrove Biomass and Carbon Stock in Demta Bay, Papua Province, Indonesia. Journal of Ecological Engineering, 22(5), 263–271. https://doi.org/10.12911/22998993/135945
27. Intergovernmental Panel on Climate Change (IPCC). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. IGES, Japan.
28. Islam, B., Ibrahim, T., Wang, T., Wu, M., & Qin, J. (2025). Current Trends in Household Food Insecurity, Dietary Diversity, and Stunting Among Children Under Five in Asia: A Systematic Review. Journal of Global Health, 15. https://doi.org/10.7189/jogh.15.04049
29. Islamy, R. A., & Hasan, V. (2020). Checklist of Mangrove Snails (Mollusca: Gastropoda) in South Coast of Pamekasan, Madura Island, East Java, Indonesia. Biodiversitas, 21(7). https://doi.org/10.13057/biodiv/d210733
30. Jing, H., Xia, X., Liu, H., Zhou, Z., Wu, C., & Nagarajan, S. (2015). Anthropogenic Impact on Diazotrophic Diversity in the Mangrove Rhizosphere Revealed by nifH Pyrosequencing. Frontiers in Microbiology, 6. https://doi.org/10.3389/fmicb.2015.01172
31. 31. Kaimuddin, M. I., Kusmana, C., & Setiawan, Y. (2023). Vegetation Structure, Biomass,
32. and Carbon of Mangrove Forests in Ambon Bay, Maluku, Indonesia. Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan, 13(4), 710–722. https://doi.org/10.29244/jpsl.13.4.710-722
33. Karim, M. R., Ahasan, S. A., & Rahman, M. A. (2025). Social-Ecological Dynamics of Sustainable Small-Scale Fisheries Management in the Sundarbans Mangrove

Forest Region, Bangladesh. Fisheries Management and Ecology, 32(5), 243–257. https://doi.org/10.1111/fme.12798
34. Kauffman, J. B., Adame, M. F., Arifanti, V. B., et al. (2020). Total Ecosystem Carbon Stocks of Mangroves Across Broad Global Environmental and Physical Gradients. Ecological Monographs, 90(2). https://doi.org/10.1002/ecm.1405
35. Komiyama, A., Poungparn, S., & Kato, S. (2005). Common Allometric Equations for Estimating the Tree Weight of Mangroves. Journal of Tropical Ecology, 21(4), 471–477. https://doi.org/10.1017/s0266467405002476
36. Korobitsyna, R., Aksenov, A., Sorokina, T., et al. (2020). Iodine Status of Women and Infants in Russia: A Systematic Review. International Journal of Environmental Research and Public Health, 17(22), 8346. https://doi.org/10.3390/ijerph17228346
37. Kuenzer, C., Bluemel, A., Gebhardt, S., Quoc, T. V., & Dech, S. (2011). Remote Sensing of Mangrove Ecosystems: A Review. Remote Sensing, 3(5), 878–928. https://doi.org/10.3390/rs3050878
38. Kulkarni, V. A., Jagtap, T. G., Mhalsekar, N. M., & Naik, A. N. (2009). Biological and Environmental Characteristics of Mangrove Habitats From Manori Creek, West Coast, India. Environmental Monitoring and Assessment, 168, 587–596. https://doi.org/10.1007/s10661-009-1136-x
39. Kundu, S., Adnani, Q. E. S., Rahman, M. A., et al. (2025). Socioeconomic Inequalities in Receiving Vitamin A Supplementation Among Children 6–59 Months in South and Southeast Asia. BMJ Nutrition Prevention & Health. https://doi.org/10.1136/bmjnph-2024-001118
40. Liberati, A., Altman, D., Tetzlaff, J., et al. (2009). The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Healthcare Interventions: Explanation and Elaboration. BMJ, 339, b2700. https://doi.org/10.1136/bmj.b2700
41. Lovelock, C. E., Cahoon, D. R., Friess, D. A., et al. (2015). The Vulnerability of Indo-Pacific Mangrove Forests to Sea-Level Rise. Nature, 526, 559–563. https://doi.org/10.1038/nature15538
42. Macintosh, D., Ashton, E. C., & Havanon, S. (2002). Mangrove Rehabilitation and Intertidal Biodiversity: A Study in the Ranong Mangrove Ecosystem, Thailand. Estuarine Coastal and Shelf Science, 55(3), 331–345. https://doi.org/10.1006/ecss.2001.0896
43. Malik, A., Fensholt, R., & Mertz, O. (2015). Mangrove Exploitation Effects on Biodiversity and Ecosystem Services. Biodiversity and Conservation, 24(14), 3543–3557. https://doi.org/10.1007/s10531-015-1015-4
44. Mao, X., Xie, W., Li, X., Shi, S., & Guo, Z. (2021). Establishing Community-Wide DNA Barcode References for Conserving Mangrove Forests in China. BMC Plant Biology, 21(1). https://doi.org/10.1186/s12870-021-03349-z
45. Meng, Y., Bai, J., Gou, R., et al. (2021). Relationships Between Above- And Below-Ground Carbon Stocks in Mangrove Forests Facilitate Better Estimation of Total Mangrove Blue Carbon. Carbon Balance and Management, 16(1). https://doi.org/10.1186/s13021-021-00172-9
46. Merven, R., Appadoo, C., Florens, F. B. V., & Iranah, P. (2023). Dependency on Mangroves Ecosystem Services Is Modulated by Socioeconomic Drivers and Socio-Ecological Changes – Insights From an Insular Biodiversity Hotspot. Research Square. https://doi.org/10.21203/rs.3.rs-2970503/v1
47. Newton, P., Oldekop, J. A., Brodnig, G., Karna, B., & Agrawal, A. (2016). Carbon, Biodiversity, and Livelihoods in Forest Commons: Synergies, Trade-Offs, and Implications for REDD+. Environmental Research Letters, 11(4). https://doi.org/10.1088/1748-9326/11/4/044017
48. Obnial, J. C., Escuadra, C. J. T., Miranda, A. V., & Lucero-Prisno, D. E. E. (2024). Infectious Disease Research in the Association of Southeast Asian Nations Region: A Scientometric Analysis. Osong Public Health and Research Perspectives, 15(4), 329–339. https://doi.org/10.24171/j.phrp.2024.0058
49. O'Connor, J., Fest, B., Sievers, M., & Swearer, S. E. (2020). Impacts of Land Management Practices on Blue Carbon Stocks and Greenhouse Gas Fluxes in Coastal Ecosystems—A Meta-analysis. Global Change Biology, 26(3), 1354–1366. https://doi.org/10.1111/gcb.14946
50. Page, M. J., McKenzie, J. E., Bossuyt, P. M., et al. (2021). The PRISMA 2020 Statement:

An Updated Guideline for Reporting Systematic Reviews. BMJ, n71. https://doi.org/10.1136/bmj.n71
51. Perera, K., & Amarasinghe, M. D. (2021). Assessment of Blue Carbon Stock of Mangroves at Malwathu Oya Estuary, Sri Lanka. Ousl Journal, 16(1), 75. https://doi.org/10.4038/ouslj.v16i1.7519
52. Pérez-Neri, I., Pineda, C., Flores-Guerrero, J. L., et al. (2022). Adherence to Literature Search Reporting Guidelines in Leading Rheumatology Journals' Systematic Reviews: Umbrella Review Protocol. Rheumatology International, 42(12), 2135–2140. https://doi.org/10.1007/s00296-022-05194-1
53. Punyapornwithaya, V., Srisawang, S., Arjkumpa, O., et al. (2025). Investigating Transboundary Spread Patterns and Cluster Characteristics of Lumpy Skin Disease Outbreaks in Asia. Transboundary and Emerging Diseases, 2025(1). https://doi.org/10.1155/tbed/2964021
54. Rachmaputra, A., Yanuwiadi, B., & Leksono, A. S. (2018). Species Diversity of Birds in Clungup Mangrove Conservation Sendang Biru, Kabupaten Malang, East Java as Bioindicator. Journal of Enviromental Engineering and Sustainable Technology, 5(2), 47. https://doi.org/10.21776/ub.jeest.2018.005.02.1
55. Richards, D. R., & Friess, D. A. (2015). Rates and Drivers of Mangrove Deforestation in Southeast Asia, 2000–2012. Proceedings of the National Academy of Sciences, 113(2), 344–349. https://doi.org/10.1073/pnas.1510272113
56. Rinjani, E. M., Khofifah, A. N., Putra Pattiasina, D. B. M., et al. (2024). Above-Ground Biomass Mapping of Mangrove Forest Using WorldView-3 Imagery in Gili Lawang, Nusa Tenggara Barat. SPIE Proceedings. https://doi.org/10.1117/12.3009661
57. Rovai, A., Twilley, R. R., Castañeda-Moya, E., et al. (2021). Macroecological Patterns of Forest Structure and Allometric Scaling in Mangrove Forests. Global Ecology and Biogeography, 30(5), 1000–1013. https://doi.org/10.1111/geb.13268
58. Sandoval, L. A. (2025). Burrowing Crabs as Potential Bioindicators of Sediment Carbon Storage in Mangroves of the Colombian Pacific. Research Square. https://doi.org/10.21203/rs.3.rs-7095077/v1
59. Sarker, M. M. H., Gain, A. K., & Giupponi, C. (2025). Modelling Mangrove Social-Ecological Systems – A Review. Environmental Research Communications, 7(6), 062001. https://doi.org/10.1088/2515-7620/addbac
60. Sasmito, S. D., Taillardat, P., Clendenning, J., et al. (2019). Effect of Land-use and Land-cover Change on Mangrove Blue Carbon: A Systematic Review. Global Change Biology, 25(12), 4291–4302. https://doi.org/10.1111/gcb.14774
61. Scemama, P., Regnier, E., Blanchard, F., & Thébaud, O. (2022). Ecosystem Services Assessment for the Conservation of Mangroves in French Guiana Using Fuzzy Cognitive Mapping. Frontiers in Forests and Global Change, 4. https://doi.org/10.3389/ffgc.2021.769182
62. Sharma, S., Ray, R., Martius, C., & Murdiyarso, D. (2023). Carbon Stocks and Fluxes in Asia-Pacific Mangroves: Current Knowledge and Gaps. Environmental Research Letters, 18(4), 044002. https://doi.org/10.1088/1748-9326/acbf6c
63. Siddiq, A. M., Wimbaningrum, R., Sulistiyowati, H., et al. (2023). The Diversity of Birds in Mangrove Forest at Biosite Pangpang Bay, Ijen Geopark. Life Science and Biotechnology, 1(2), 52. https://doi.org/10.19184/lsb.v1i2.44165
64. Stiepani, J., Gillis, L. G., Chee, S. Y., Pfeiffer, M., & Nordhaus, I. (2021). Impacts of Urbanization on Mangrove Forests and Brachyuran Crabs in Penang, Malaysia. Regional Environmental Change, 21(3). https://doi.org/10.1007/s10113-021-01800-3
65. Sudirman, N., Helmi, M., & Adi, N. S. (2018). Modeling Mangrove 'Blue Carbon' Ecosystem Service in Jakarta Bay as an Impact of Coastal Development. E3S Web of Conferences, 73, 04023. https://doi.org/10.1051/e3sconf/20187304023
66. Surahman, E., & Wang, T. (2022). Academic Dishonesty and Trustworthy Assessment in Online Learning: A Systematic Literature Review. Journal of Computer Assisted Learning, 38(6), 1535–1553. https://doi.org/10.1111/jcal.12708
67. Tang, P. P., Tam, I. L., Jia, Y., & Leung, S. (2022). Big Data Reality Check (BDRC) for Public Health: To What Extent the

Environmental Health and Health Services Research Did Meet the 'V' Criteria for Big Data? BMJ Open, 12(3), e053447. https://doi.org/10.1136/bmjopen-2021-053447

68. Tian, Y., Hu, H., Zhou, G., et al. (2023). Mangrove Biodiversity Assessment Using UAV Lidar and Hyperspectral Data in China's Pinglu Canal Estuary. Remote Sensing, 15(10), 2622. https://doi.org/10.3390/rs15102622
69. Tricco, A. C., Lillie, E., Zarin, W., et al. (2018). PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Annals of Internal Medicine, 169(7), 467–473. https://doi.org/10.7326/m18-0850
70. Vu, N. T. T., Zenger, K. R., Silva, C. N. S., Guppy, J. L., & Jerry, D. R. (2021). Population Structure, Genetic Connectivity, and Signatures of Local Adaptation of the Giant Black Tiger Shrimp (Penaeus monodon). Genome Biology and Evolution, 13(10). https://doi.org/10.1093/gbe/evab214
71. Wahab, M. K. A., Zulkifli, H., & Razak, K. A. (2022). Impact of Philosophy for Children and Its Challenges: A Systematic Review. Children, 9(11), 1671. https://doi.org/10.3390/children9111671
72. Wainwright, B. J., Millar, T., Bowen, L., et al. (2022). The Mangrove Microbiome of the Malay Peninsula. Microbiology Spectrum. https://doi.org/10.1101/2022.11.21.517418
73. Wee, A. K. S., Salmo, S. G., Sivakumar, K., et al. (2023). Prospects and Challenges of Environmental DNA (eDNA) Metabarcoding in Mangrove Restoration in Southeast Asia. Frontiers in Marine Science, 10. https://doi.org/10.3389/fmars.2023.1033258
74. Willingness to Pay for Conservation of Mangrove Forest in Kuala Perlis, Malaysia. (2020). Jurnal Ekonomi Malaysia, 54(3), 89–99. https://doi.org/10.17576/jem-2020-5403-07
75. Yang, Y., Li, J., Yang, S., et al. (2017). Effects of Pleistocene Sea-Level Fluctuations on Mangrove Population Dynamics: A Lesson From Sonneratia alba. BMC Evolutionary Biology, 17(1). https://doi.org/10.1186/s12862-016-0849-z

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