Ethnobotanical knowledge in mangrove rehabilitation: A systematic and bibliometric review of species-use patterns and community-based practice

Amelia Suryanita, Ari Anggoro, Nella Tri Agustini, Yola Wulandari, Rayana Rayana, Feldy Khalid, Muh Akbar Idris

Correspondence

Amelia Suryanita[1], Ari Anggoro[2], Nella Tri Agustini[2] Yola Wulandari[1], Rayana Rayana[3], **Feldy Khalid**[4], **Muh Akbar Idris**[5,6*]

[1]Department of Marine Science, Faculty of Fisheries and Marine Science, IPB University, Bogor, Indonesia.
[2]Marine Science Study Program, Faculty of Agriculture, University of Bengkulu, Bengkulu 38371, Indonesia.
[3]Department of Management Science, IPB University, Bogor, Indonesia.
[4]Department of Agricultural and Rural Development Communication, IPB University, Bogor, Indonesia.
[5]School of Data Science, Mathematics, and Informatics, IPB University, Bogor, Indonesia.
[6]Faculty of Mathematics and Natural Sciences, Universitas Sulawesi Barat, Majene, Indonesia.

*Corresponding Author: muhakbaridris@gmail.com

Ethnobotany Research and Applications 35:59 (2026) - http://dx.doi.org/10.32859/era.35.59.1-19
Manuscript received: 17/06/2026 - Revised manuscript received:29/08/2026- Published: 02/09/2026

Research

Abstract

Background: Mangrove rehabilitation is commonly evaluated through planting area, seedling survival, and ecosystem services. The ways in which coastal communities know, use, and discuss mangrove species are less consistently synthesized, particularly in relation to rehabilitation practice.

Methods: A PRISMA-based review of 262 Scopus-indexed studies published between 1991 and 2026 combined metadata-based thematic coding with descriptive bibliometrics, Mann-Kendall trend analysis, negative binomial regression, country-level summaries, and keyword-network analysis. Practical themes were summarized from an empirical-oriented subset of 229 records, while 33 secondary publications were flagged separately.

Results: The 262 studies were published in 177 normalized sources and received 6,071 citations. Annual publication counts increased over the review period (Kendall's tau = 0.753, $p < 0.001$); the negative binomial model estimated an annual incidence rate ratio of 1.148 (95% CI 1.123-1.174). Across 87 identified countries, full-count document contributions were unequal (Gini = 0.604) but not dominated by a single country (HHI = 361). Document counts and citations were not associated across the ten leading countries (Spearman's rho = -0.006, $p = 0.987$). The author-keyword network contained 25 nodes and 90 edges with weak modular separation (Q = 0.166). In the empirical-oriented subset, cultural or ritual and livelihood or economic themes accounted for 149 and 81 of 380 metadata-based use flags, respectively.

Conclusions: The reviewed literature consistently places local plant knowledge, species use, and community participation within discussions of mangrove rehabilitation. These patterns identify practical considerations for species selection and long-term stewardship, but they do not demonstrate that local use causes a species to be selected or improves field survival. Field-based studies are needed to test those relationships directly.

Keywords: Ethnobotany, Mangrove rehabilitation, Systematic review, Bibliometrics, Traditional ecological knowledge, Species-use patterns, Community participation, Blue carbon

Background

Ethnobotany provides a useful perspective on mangrove rehabilitation because mangrove species are ecological components of coastal forests and plants that may be known, used, valued, and managed by nearby communities (Walters *et al.* 2008, Rao *et al.* 2022). More broadly, ethnobotanical research shows that knowledge and biodiversity use are closely connected in resource-dependent settings (Begossi *et al.* 2000). Studies from mangrove-dependent landscapes document knowledge of plant parts, harvesting practices, food resources, medicinal uses, wood products, household materials, and cultural or livelihood values (Dahdouh-Guebas *et al.* 2000, Siregar *et al.* 2025). Together, this work describes how everyday use, ecological observation, and knowledge transmission shape human-mangrove relationships.

Mangrove uses and local knowledge

Reported mangrove uses include food, medicine, timber, construction material, fuelwood, fodder, tannin, household products, and cultural or livelihood practices (Rao *et al.* 2022, Siregar *et al.* 2025). Research in North Sumatra, for example, documented plant uses through interviews, guided forest walks, voucher specimens, and ethnobotanical indices (Siregar *et al.* 2025). Reviews and case studies from Indonesia, Kenya, and Cameroon likewise show that edible species and wood products remain connected with household needs, markets, and local perceptions of change (Dahdouh-Guebas *et al.* 2000, Atheull *et al.* 2009, Nfotabong-Atheull *et al.* 2011, Basyuni *et al.* 2025). Additional case studies from Mozambique, India, Sri Lanka, Tanzania, and Saint Lucia document links among mangrove biodiversity, resource use, livelihoods, conservation, and community-based management (Come *et al.* 2023, Dahdouh-Guebas *et al.* 2006, Mafaziya Nijamdeen *et al.* 2023, Semesi 1998, Smith & Berkes 1993). Traditional wood use on the Brazilian Amazon coast and medicinal plant knowledge in the Indian Sundarbans further show that the relevance of plant use differs across places and taxa (Galvão *et al.* 2024, Mullick *et al.* 2025).

Despite this ethnobotanical richness, mangrove rehabilitation is often discussed through planting targets, seedling survival, canopy development, ecosystem services, or carbon-related outcomes (Walters 2000, Rönnbäck *et al.* 2007). These indicators are important, but they do not fully explain how communities select, accept, maintain, or evaluate planted mangrove species (Nguyen *et al.* 2016a, Rönnbäck *et al.* 2007). Local mangrove planting in the Philippines shows that community-based species choice can be shaped by familiarity, available propagules, and practical planting experience, particularly through the frequent use of Rhizophora species (Walters 2000). Replanted mangrove forests in Kenya were also evaluated by local communities through the return of ecosystem goods and services (Rönnbäck *et al.* 2007).

Species selection and community participation

Species selection in mangrove rehabilitation should begin with ecological suitability, including hydrology, substrate, salinity, natural zonation, and site-specific constraints (Biswas *et al.* 2009, Nguyen *et al.* 2016b). Ethnobotanical information can complement that assessment by identifying species that are familiar, locally available, or connected with practical use. The reviewed studies suggest that such familiarity may be relevant to community attention and maintenance, but they do not quantify its effect on planting decisions or survival (Walters 2000, Siregar *et al.* 2025). A combined assessment therefore provides a basis for field discussion rather than a fixed rule for species choice.

Community capacity and knowledge exchange are also relevant because local knowledge has practical value only when it can be discussed, adapted, and applied. Studies from Vietnam and Indonesia show how local people interpret project goals, benefits, responsibilities, and management needs, and how participatory mapping can identify benefits that matter locally (Nguyen *et al.* 2016a, Damastuti & de Groot 2019). Related work on community-based management supports involving local actors as knowledge holders and participants, while leaving the effectiveness of particular engagement approaches to be tested in each setting (Dhyani *et al.* 2023, Barrera-Bello *et al.* 2025). Earlier research also shows that farmers' rationalities and the integration of indigenous and scientific knowledge can shape how natural-resource interventions are interpreted and negotiated (Dries 1991, Rist & Dahdouh-Guebas 2006). Evidence from the Bangladesh Sundarbans further links erosion of traditional ecological knowledge with concerns about community resilience (Saha *et al.* 2026).

Blue carbon is relevant to mangrove rehabilitation as a possible long-term outcome rather than the central claim of an ethnobotanical review. Carbon benefits depend on ecological feasibility, governance, monitoring, restoration success, and long-term protection (Macreadie *et al.* 2022, Hagger *et al.* 2024). Studies of Indigenous stewardship and co-management

further suggest that local governance and community knowledge may provide important social context for blue carbon initiatives, although these relationships require site-specific evaluation (Costa *et al.* 2026).

Analytical scope and review objectives

Bibliometric analysis can describe how a field develops, where studies are produced, and which concepts frequently occur together. Recent ethnobotanical studies likewise use spatial-statistical and bibliometric approaches to map research patterns and methodological development (Idris *et al.* 2026, Limba *et al.* 2026). It cannot, however, substitute for field measurements of planting decisions, survival, maintenance, or rehabilitation outcomes. The present review therefore uses publication and coding data to characterize patterns in the literature and interprets their implications cautiously.

This review has three objectives: (1) to describe the temporal, geographic, and thematic structure of literature linking mangrove ethnobotany with rehabilitation; (2) to summarize how local uses, plant parts, species-level knowledge, community participation, and knowledge exchange are represented in that literature; and (3) to propose a review-based framework that can guide, but does not replace, field-based evaluation of species selection, ecological suitability, community stewardship, and potential long-term blue carbon outcomes.

Materials and Methods

This study used a systematic literature review with thematic coding and bibliometric analysis. A PRISMA 2020-based workflow was used to document identification, screening, eligibility assessment, and inclusion. Statistical analyses were applied to publication-level patterns; they were not used as proxies for field rehabilitation outcomes.

Study Design and Data Collection

Data were retrieved from Scopus because it indexes peer-reviewed literature across environmental, biological, agricultural, and social sciences. The archived export is dated 14 June 2026. The search combined three concept blocks: mangrove ecosystems or taxa, ethnobotanical or local knowledge, and rehabilitation-related practice. Searches were limited to titles, abstracts, and keywords; no language restriction was applied at the search stage.

Table 1. Main research parameters and screening summary used in the systematic literature review.

Parameter	Description
Database	Scopus
Review type	Systematic review with thematic synthesis and bibliometric analysis
Screening framework	PRISMA 2020-based workflow
Search coverage closed	14 June 2026
Analytical tools	VOSviewer (network visualization); R (bibliometrix, stats, igraph, FactoMineR, MASS, Kendall); thematic coding
Initial records	365
Duplicates removed	1
Reports assessed for eligibility	360
Reports excluded	98
Studies included	262
Main synthesis focus	Ethnobotanical knowledge, local uses, species-use patterns, community participation, and rehabilitation implications

Scopus search expression: TITLE-ABS-KEY((mangrove* OR Rhizophora OR Avicennia OR Sonneratia OR Bruguiera OR Ceriops OR Xylocarpus OR Nypa) AND (ethnobotan* OR "traditional knowledge" OR "local ecological knowledge" OR "indigenous knowledge" OR "plant use*" OR "local use*" OR "medicinal use*" OR "cultural value*" OR livelihood*) AND (rehabilitat* OR restor* OR replant* OR "species selection" OR "community participation" OR "community capacity" OR "knowledge transfer" OR "blue carbon" OR "ecosystem service*")). The expression was confirmed against the concept blocks recorded in the review protocol and is reported as the definitive documented query for this review.

The search identified 365 records. Duplicate checking used normalized DOI together with title and author information. One article-in-press/final-record pair was collapsed, leaving 364 records for title and abstract screening. A shared book-level DOI attached to two different chapters was not treated as a duplicate. Four records were excluded because they lacked an ethnobotanical, local-knowledge, or local-use component. The remaining 360 reports were assessed for eligibility, and 98

were excluded because they did not link the focal topic to rehabilitation, species selection, community participation or capacity, or a restoration implication. The final synthesis included 262 records. The archived screening log operationalized these criteria with Boolean fields derived from titles, abstracts, author keywords, and index keywords. It also flagged 33 secondary publications and 14 biochemically or medically focused records for separate interpretation. An independent double-screening log and a formal inter-rater reliability coefficient were not available; this is acknowledged as a limitation.

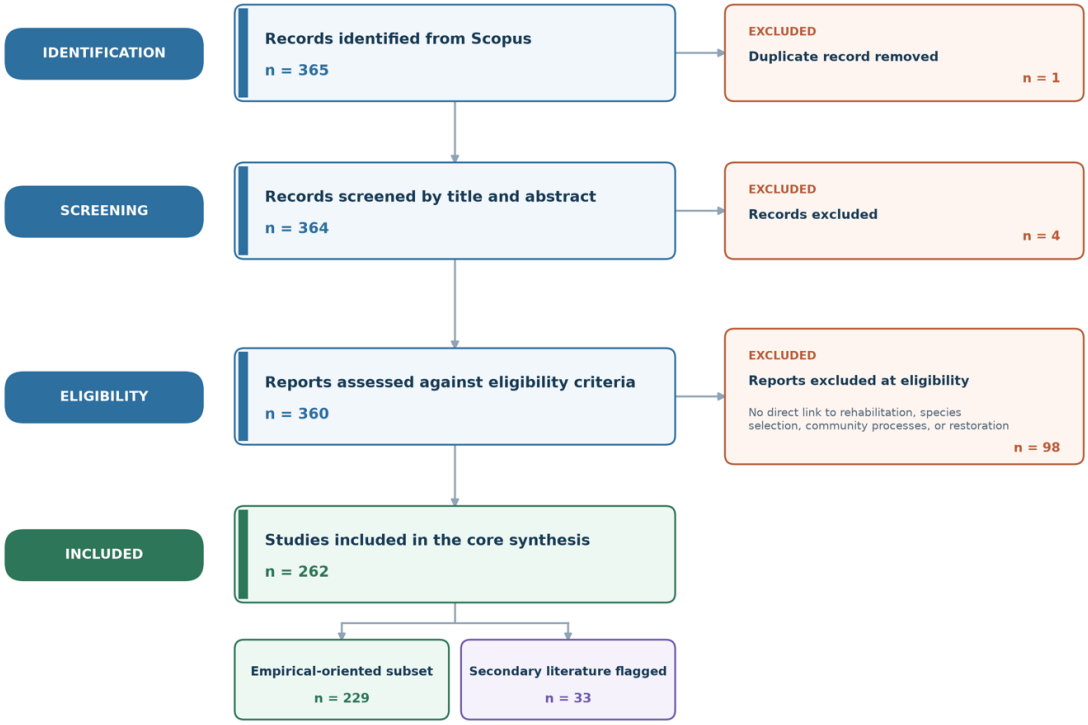

Figure 1. PRISMA flow diagram for the systematic selection of studies on ethnobotanical knowledge and mangrove rehabilitation.

Thematic Coding

Each retained record was coded for mangrove species or taxa, plant parts used, local-use categories, traditional or local ecological knowledge, relevance to species selection, community participation or capacity, communication processes, and restoration implications. Local uses were grouped into eight non-mutually-exclusive categories: cultural or ritual, livelihood or economic, food, timber or construction, medicinal, fuelwood or charcoal, fodder, and tannin or dye. The archived flags were generated from the combined title, abstract, author-keyword, and index-keyword fields. They therefore indicate whether a theme was represented in the metadata; they are not equivalent to standardized full-text effect extraction. The 229 records not flagged as secondary literature were used for the main practical-theme summary, and the 33 secondary records were retained for bibliometric coverage but interpreted separately. Because the review synthesized bibliographic and thematic patterns rather than intervention effects, a conventional intervention risk-of-bias score was not applied.

Statistical Analysis

Analyses were recomputed in *R version* 4.6.1 using bibliometrix-compatible field definitions, MASS for negative binomial regression, and igraph for network metrics. The analysis distinguished inferential models of annual publication counts from descriptive summaries of country contributions, citations, keyword structure, and thematic coding.

Descriptive statistics. Annual and cumulative publication counts, document age, citations per document, author productivity, journal productivity, and international co-authorship were summarized with counts, percentages, means, medians, and standard deviations as appropriate.

Trend analysis. Annual publication counts were evaluated with the non-parametric Mann-Kendall test (Mann 1945, Kendall 1975), and the magnitude of the monotonic trend was estimated with Sen's slope (Sen 1968). Poisson and negative binomial generalized linear models were compared. The negative binomial model was retained because the Poisson dispersion estimate exceeded one and the negative binomial model had the lower AIC. The previously considered polynomial regression

was omitted from the revised analysis to avoid overinterpreting a short and uneven annual series, particularly because 2026 was incomplete.

Geographic concentration and impact-productivity association. A document contributed once to every country identified in its affiliation field (full counting); five records had no usable country affiliation. The Gini coefficient and the Herfindahl-Hirschman Index (HHI) were calculated across all 87 identified countries. These indices describe the review corpus and were not treated as estimates from a random sample. The association between document count and total citations across the ten leading countries was examined with Spearman rank correlation. A non-significant result was interpreted as insufficient evidence of association, not as proof of decoupling.

Keyword co-occurrence network analysis. Author keywords appearing in at least five documents were represented as an undirected weighted network. Degree, betweenness, and eigenvector centrality were calculated for each node. Community structure was identified with the Louvain modularity algorithm. Network-level descriptors included node and edge counts, density, average degree, connected components, and the global clustering coefficient.

Local-use categories. Because records could receive more than one metadata-based use flag and unequal category frequencies were expected on substantive grounds, category counts were summarized descriptively for the 229-record empirical-oriented subset. Counts and shares of all flags were reported. Uniform-distribution chi-square tests, pairwise contrasts, standardized residuals, and Cramer's V were removed because they did not answer a theoretically justified inferential question.

Species-use synthesis. Species, plant parts, local uses, and rehabilitation relevance were summarized in a structured evidence table. Species-level relationships were interpreted as exploratory patterns in the reviewed literature. Multivariate ordination and clustering were not retained because the small focal set, non-mutually-exclusive categories, and unavailable archived loading matrix did not support reproducible or stable cluster claims.

Reproducibility. All reported analyses used the 262-record core dataset derived from the archived 365-record Scopus export. The derived and pseudonymized screening log, PRISMA summary, exclusion-reason table, 229-record empirical-oriented subset, 33-record secondary-literature subset, local-use summary, R analysis script, verified outputs, and Supplementary Materials are publicly archived in Zenodo (Suryanita *et al.* 2026). The raw Scopus export and copied bibliographic text are not redistributed because database licensing may restrict public redistribution.

Results

Bibliometric Descriptive Statistics

The 262 included studies were published across 177 normalized sources between 1991 and 2026. Table 2 summarizes the principal bibliometric descriptors of the audited core dataset.

Table 2. Bibliometric summary statistics of the analyzed mangrove ethnobotany dataset.

Indicator	Value
Timespan	1991-2026
Sources (journals, books, proceedings)	177
Documents	262
Compound annual growth rate (%)	10.41%
Mean document age	6.21 years
Citations per document	Mean 23.17; SD 82.96; median 6.5
Total citations	6,071
Author keywords (DE)	928
Unique Scopus author IDs	1,180
Authors per document	Mean 4.90; SD 4.54
Single-authored documents	36 (13.7%)
International co-authorship	115 (43.9%)

Across the corpus, mean document age was 6.21 years. Citations were strongly right-skewed (mean = 23.17, SD = 82.96; median = 6.5 per document), so a small number of highly cited publications accounted for a substantial share of citations. The file contained 1,180 unique Scopus author IDs; documents had a mean of 4.90 authors (SD = 4.54), and 36 documents

(13.7%) were single-authored. Based on distinct affiliation countries, 115 documents (43.9%) involved international co-authorship.

Annual Publication Trends

The annual distribution of publications shows limited and irregular output between 1991 and the early 2000s, followed by a gradual increase after 2006 and a more pronounced rise after 2022. The highest annual output was recorded in 2025, while the lower count in 2026 should be interpreted carefully because the publication year was still incomplete at the time of data collection.

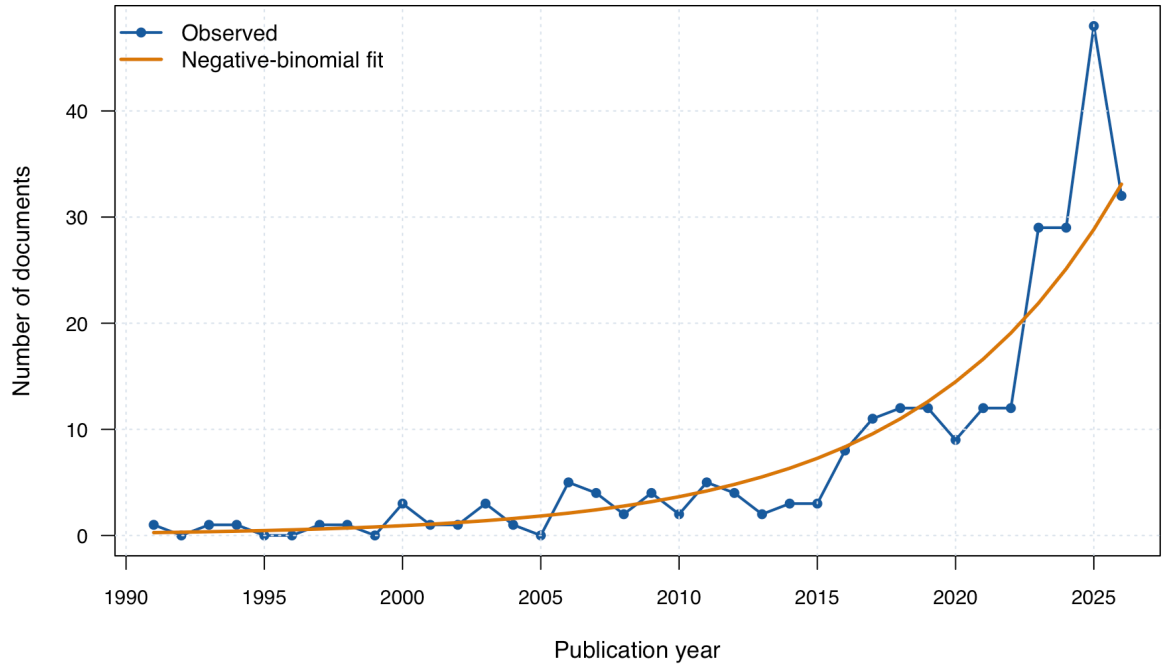

Figure 2. Annual publication trend of the 262 studies included in the systematic review, showing publication growth from 1991 to 2026.

The Mann-Kendall test indicated a monotonic increase in annual publication counts (Kendall's tau = 0.753, $p < 0.001$), and Sen's slope was 0.44 publications per year. The negative binomial model estimated an annual coefficient of 0.138 (SE = 0.011, $p < 0.001$), equivalent to an incidence rate ratio of 1.148 (95% CI 1.123-1.174). The Poisson dispersion estimate was 1.50, and the negative binomial model had a slightly lower AIC than the Poisson model (154.3 versus 156.5). These statistics describe growth in the indexed literature and should not be interpreted as a forecast; the 2026 count was incomplete at the coverage cutoff.

India had the largest full-count document contribution (44 documents), closely followed by Indonesia (42), while the United States (31), Australia (29), Brazil (26), and the United Kingdom (24) also represented major contributors. This distribution suggests that the literature is produced through an interaction between countries with extensive mangrove ecosystems and countries functioning as international research and collaboration hubs. India and Indonesia, for example, represent mangrove-rich contexts in which ethnobotanical knowledge, community use, and rehabilitation are directly relevant to coastal landscapes, whereas the United States, Australia, and the United Kingdom occupy prominent positions within broader international research networks. Belgium also showed a comparatively high citation total despite a smaller document contribution, further illustrating that publication volume and citation accumulation do not necessarily follow the same geographic pattern.

The recent increase in publications indicates growing scholarly attention to the relationships among mangrove rehabilitation, local knowledge, community participation, and ecosystem services. This expansion may also reflect broader interest in nature-based solutions and blue carbon. Nevertheless, the trend represents growth in the indexed literature and should not be interpreted as direct evidence of increased rehabilitation activity or improved field outcomes.

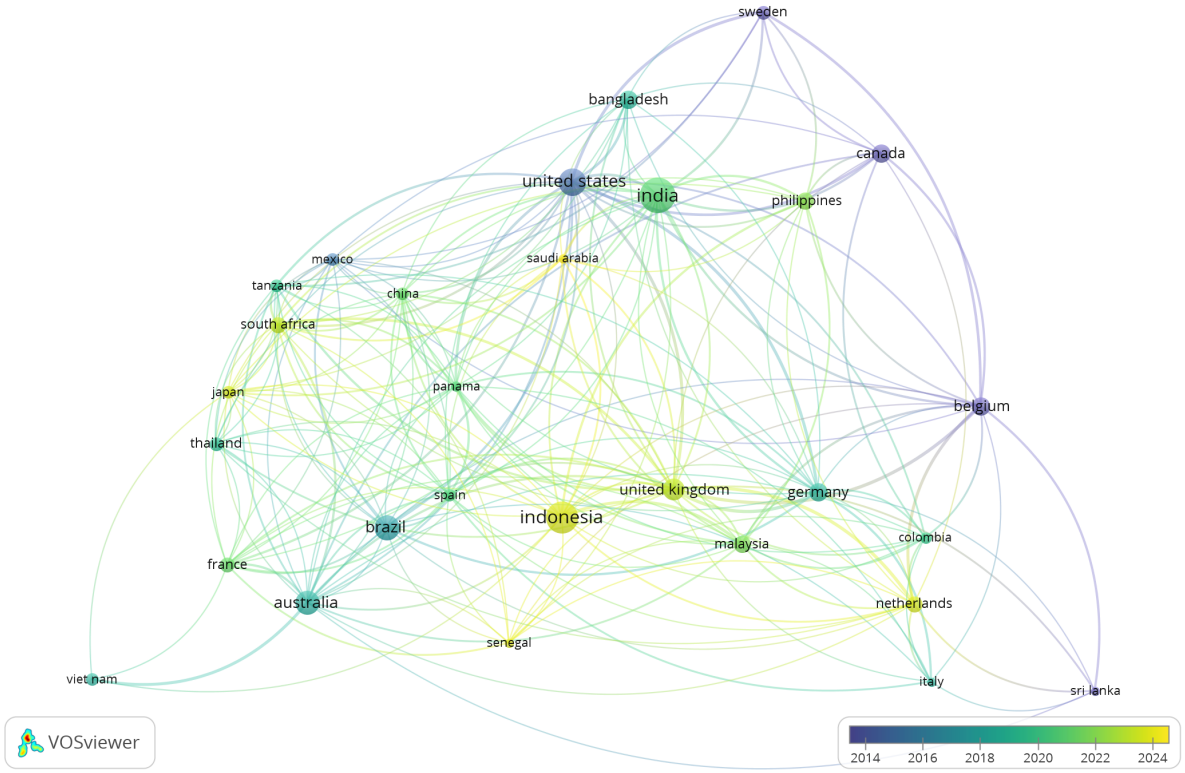

Figure 3. Country co-authorship network for the 20 leading countries in the reviewed literature. Node size represents document count, and edge width represents the number of shared documents.

Table 3. Leading countries in the reviewed literature, with document counts, citations, total link strength, and concise contextual notes.

Rank	Country	Documents	Citations	Total link strength	Ethnobotanical relevance
1	India	44	920	46	Mangrove and delta research setting.
2	Indonesia	42	235	31	Mangrove-rich community-use setting.
3	United States	31	1,238	78	International research hub.
4	Australia	29	748	57	Restoration and blue-carbon research hub.
5	Brazil	26	502	28	Amazonian and coastal research setting.
6	United Kingdom	24	294	85	International collaboration hub.
7	Belgium	15	1,236	40	Mangrove ethnobiology hub.
8	Philippines	15	693	23	Community-based mangrove research setting.
9	Germany	15	197	49	Ecology and management hub.
10	Canada	13	1,188	16	Social-ecological collaboration hub.

Across all 87 identified countries, the full-count contribution distribution had a Gini coefficient of 0.604 and an HHI of 361. The Gini value reflects a long tail of countries with few publications, whereas the low HHI indicates that no single country dominated the corpus. Spearman's rank correlation between document counts and total citations among the ten leading countries was essentially zero (rho = -0.006, p = 0.987). Accordingly, the analysis provides no clear evidence that countries publishing more documents also received more citations within this small country-level comparison.

Keyword Co-occurrence, Network Centrality, and Community Detection

The keyword co-occurrence network was used to examine how recurring author keywords were connected. With a minimum occurrence threshold of five documents, the network contained 25 nodes and 90 edges. Network-level statistics and the most central keywords are reported below.

At the five-document threshold, the author-keyword network contained 25 nodes and 90 edges, with density 0.300, mean degree 7.20, and a global clustering coefficient of 0.441. Louvain detection returned four communities with Q = 0.166. This low modularity indicates weak separation rather than well-defined thematic clusters.

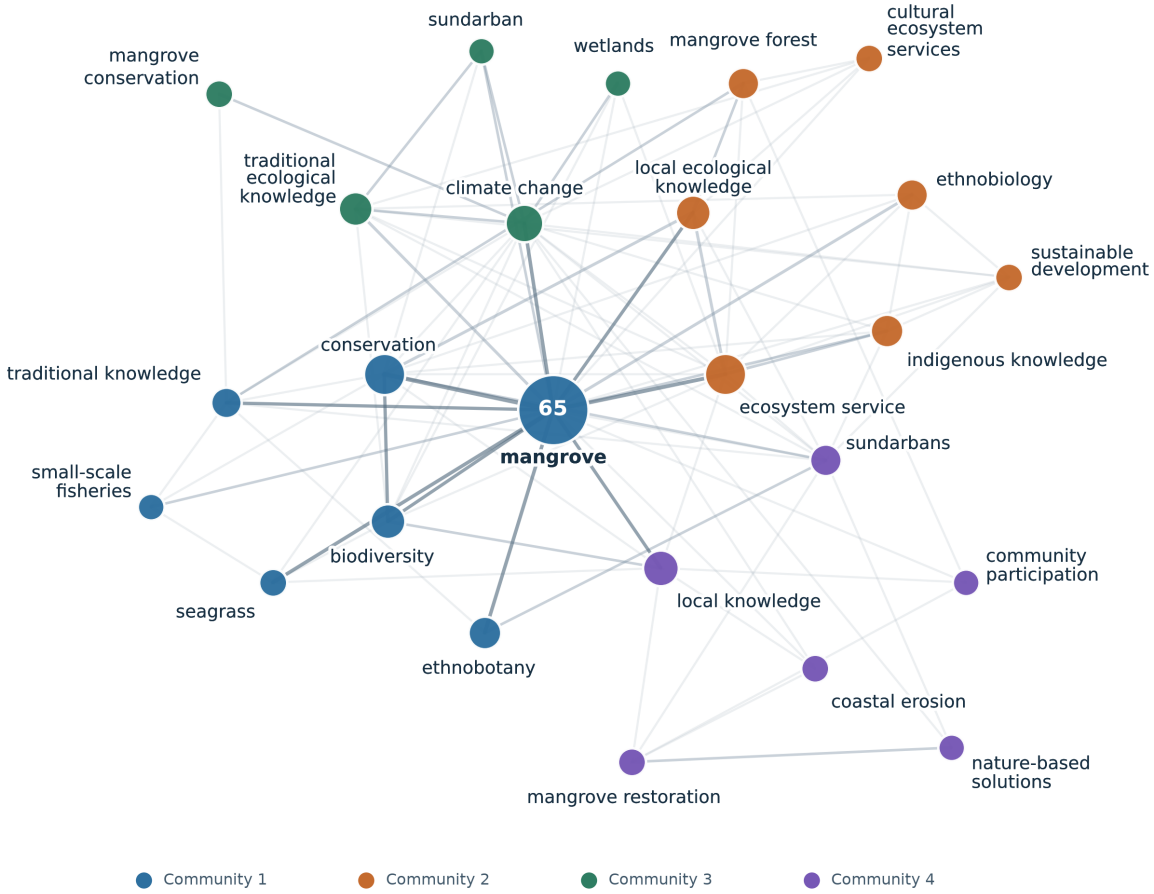

Figure 4. Author-keyword co-occurrence network at a five-document threshold. Node size represents keyword occurrence, edge width represents co-occurrence frequency, and color indicates Louvain community membership.

Table 4. Top keywords ranked by occurrence and centrality measures from the keyword co-occurrence network (25 nodes, 90 edges).

Rank	Keyword	Occur.	Degree	Betw.	Eigen.	Community
1	mangrove	65	0.833	0.761	1.000	1
2	ecosystem service	19	0.542	0.000	0.481	2
3	conservation	19	0.500	0.065	0.625	1
4	climate change	15	0.667	0.232	0.426	3
5	local knowledge	13	0.333	0.065	0.297	4
6	biodiversity	12	0.333	0.000	0.404	1
7	local ecological knowledge	12	0.250	0.041	0.364	2
8	traditional ecological knowledge	11	0.375	0.004	0.270	3
9	indigenous knowledge	10	0.292	0.000	0.214	2
10	ethnobotany	10	0.125	0.000	0.267	1
11	sundarbans	9	0.500	0.005	0.233	4
12	ethnobiology	9	0.250	0.000	0.220	2

Mangrove had the highest degree (0.833), betweenness (0.761), and eigenvector centrality (1.000), as expected for the domain-defining term. Climate change had the next-highest betweenness value (0.232), while conservation and local knowledge each had a value of 0.065. These positions describe keyword connectivity only; they do not establish practical influence on rehabilitation decisions.

Local Use Categories: Descriptive Frequency Distribution

The thematic coding identified eight major categories of mangrove local uses in the reviewed literature, summarized in Table 5.

Table 5. Frequency and share of metadata-based local-use flags in the 229-record empirical-oriented subset. Categories were non-mutually exclusive.

Rank	Local use category	Observed	Share of mentions (%)	Relative frequency	Concise interpretation
1	Cultural/ritual uses	149	39.2	Most frequent	Identity, ritual, and community values
2	Livelihood/economic uses	81	21.3	Frequent	Income and household economic activities
3	Food use	43	11.3	Moderate	Edible resources and processed products
4	Timber/construction	42	11.1	Moderate	Poles, housing materials, and tools
5	Medicinal use	28	7.4	Moderate	Local health practices and remedies
6	Fuelwood/charcoal	21	5.5	Less frequent	Household fuel and charcoal
7	Fodder	11	2.9	Less frequent	Animal feed and livestock support
8	Tannin/dye	5	1.3	Less frequent	Tanning and dye materials

The 229-record empirical-oriented subset generated 380 metadata-based local-use flags. Cultural or ritual uses were the most frequent (149 flags; 39.2%), followed by livelihood or economic uses (81; 21.3%). Food (43; 11.3%), timber or construction (42; 11.1%), and medicinal uses (28; 7.4%) formed a middle group, while fuelwood or charcoal (21; 5.5%), fodder (11; 2.9%), and tannin or dye (5; 1.3%) were less frequent. Because categories overlapped and were derived from metadata rather than standardized full-text coding, these values describe representation in the records, not prevalence of use in coastal communities.

Species, Plant Parts, and Exploratory Synthesis

Table 6 summarizes representative links among focal taxa, plant parts, local uses, and rehabilitation-related discussion. The table is intended to help readers compare the kinds of values associated with different taxa. It does not measure community planting choices, maintenance effort, seedling survival, or ecological performance.

Table 6. Representative examples of mangrove species, plant parts, local uses, and rehabilitation relevance identified from the reviewed literature.

Species/taxa	Plant part or resource	Main local use	Relevance to rehabilitation	Representative studies
Nypa fruticans	Leaves, fruits, sap, stems	Food products, roofing materials, cigarette paper, household use, livelihood resources	Connects food, household materials, income, and local knowledge.	Cheablam & Chanklap 2020; Siregar *et al.* 2025; Basyuni *et al.* 2025
Bruguiera gymnorrhiza	Fruits, leaves, wood, other plant parts	Food, medicinal use, construction, fuelwood	Illustrates multiple edible, medicinal, and material uses.	Dahdouh-Guebas *et al.* 2000; Basyuni *et al.* 2025; Wintah *et al.* 2026
Acanthus ilicifolius	Leaves and whole plant	Medicinal use, local health-related practices	Represents medicinal knowledge of mangrove-associated plants.	Siregar *et al.* 2025; Wintah *et al.* 2026
Rhizophora spp.	Propagules, seedlings, wood	Planting material, construction, fuelwood, restoration planting	Common planting material; suitability remains site dependent.	Walters 2000; Dahdouh-Guebas *et al.* 2000; Nguyen *et al.* 2016b
Avicennia spp.	Seedlings, leaves, bark, wood	Nursery production, medicinal use, restoration planting, silvo-aquaculture relevance	Links nursery work with medicinal and production-system uses.	Nguyen *et al.* 2016b; Rahman *et al.* 2020; Wintah *et al.* 2026
Sonneratia spp.	Seedlings, fruits, wood, other plant parts	Nursery production, food-related use, medicinal use, silvo-aquaculture relevance	Combines nursery, food, medicinal, and production-system contexts.	Nguyen *et al.* 2016b; Rahman *et al.* 2020; Wintah *et al.* 2026; Basyuni *et al.* 2025
Mangrove wood taxa (Rhizophora, Ceriops, Bruguiera, Sonneratia, Xylocarpus)	Stems, branches, bark, logs	House construction, fuelwood, charcoal, boat building, poles, furniture, tanning materials	Shows continued household and subsistence demand for wood products.	Dahdouh-Guebas *et al.* 2000; Rao *et al.* 2022

Across the representative studies, Nypa fruticans and Bruguiera gymnorrhiza were often discussed in relation to food, household, and material uses. Rhizophora, Avicennia, and Sonneratia were more often linked with nursery or planting contexts, sometimes alongside food or medicinal uses. Acanthus ilicifolius was mainly represented in medicinal contexts, while Ceriops and Xylocarpus appeared mainly in discussions of wood and other material uses.

These groupings are an exploratory reading of the coded literature, not statistically validated species clusters. Their practical relevance therefore depends on field assessment of hydrology, substrate, salinity, natural zonation, propagule availability, community preference, and long-term management capacity.

Discussion

Interpreting Bibliometric and Ethnobotanical Patterns

This review combines publication-trend and keyword-network analyses with a thematic synthesis of local uses and rehabilitation-related discussion. The bibliometric results describe the organization of the literature. They do not test whether ethnobotanical knowledge determines species selection or improves rehabilitation outcomes. Maintaining this distinction is important because publication frequency, keyword centrality, and thematic coding are evidence about research attention, not direct measurements of community behavior or ecological performance.

Ethnobotanical Knowledge and Local Plant Uses in Mangrove Rehabilitation

The reviewed literature presents mangrove species as both ecological components of coastal forests and plants that communities may know, use, value, and manage (Walters *et al.* 2008, Rao *et al.* 2022, Siregar *et al.* 2025). Cultural or ritual and livelihood or economic themes were flagged most often in the empirical-oriented subset, but this frequency may reflect the scope of the indexed literature as well as conditions in coastal communities. The result supports closer attention to these themes without implying that they are universally dominant or causally determine rehabilitation choices.

The species-use synthesis adds practical detail to this interpretation. Food and household uses were prominent for Nypa fruticans and Bruguiera gymnorrhiza; nursery and planting contexts were common for Rhizophora, Avicennia, and Sonneratia; and medicinal or material-use contexts were more prominent for Acanthus, Ceriops, and Xylocarpus. These are useful distinctions for developing field questions, but they should be validated with community-level and site-level data before they guide species selection.

Species Selection as an Ethnobotanical and Ecological Process

Species selection is a point at which ethnobotanical knowledge may contribute to mangrove rehabilitation. The reviewed studies suggest that familiarity, local availability, practical use, and knowledge of plant parts can be relevant considerations (Walters 2000, Rönnbäck *et al.* 2007, Nguyen *et al.* 2016a). The present review did not observe planting decisions directly, so it cannot estimate the strength or direction of those relationships.

Ethnobotanical relevance should complement, not replace, ecological assessment. The frequent use of Rhizophora in community planting illustrates this balance: familiar propagules may facilitate participation, but site selection still needs to consider hydrology, substrate, salinity, tidal exposure, and natural zonation (Walters 2000, Nguyen *et al.* 2016b, Nguyen *et al.* 2017b). Locally valued species may receive attention from communities, yet long-term establishment still depends on ecological suitability and continued management.

Geographic and Network Structure of the Literature

Country contributions were unequal across the full set of identified countries (Gini = 0.604), but the HHI of 361 indicates that the corpus was not dominated by one country. The country-level correlation between document count and citations among the ten leading countries was not significant (rho = -0.006, p = 0.987). This result indicates uncertainty about the association; it does not demonstrate that productivity and influence are separate or decoupled processes.

The keyword network showed weak modular separation (Q = 0.166). Knowledge-related terms occurred alongside ecological, conservation, climate, and community themes, but no stable, well-separated knowledge cluster was evident at the selected threshold. The finding is bibliometric and should not be used as evidence that traditional knowledge has already been integrated into rehabilitation programs.

Community Capacity, Knowledge Transfer, and Long-term Stewardship

Community capacity matters because local knowledge can contribute to rehabilitation only when it is communicated and applied through activities such as dialogue, nursery work, monitoring, and maintenance (Nguyen *et al.* 2016a, Nguyen *et al.* 2017a, Del Cid-Alvarado *et al.* 2024). However, the review coded how publications discussed these processes; it did not measure training outcomes, institutional capacity, knowledge retention, or stewardship over time. These relationships require primary research with clearly defined indicators.

Restoration Implications and Potential Blue Carbon Benefits

Ethnobotanically informed rehabilitation may contribute to broader restoration implications, including ecosystem services, livelihood support, cultural continuity, coastal protection, biodiversity recovery, and potential blue carbon benefits. Local communities in replanted mangrove areas may evaluate restoration through the return of ecosystem goods and services, showing that rehabilitation outcomes can be understood through locally meaningful benefits as well as ecological recovery (Rönnbäck *et al.* 2007). Participatory ecosystem service mapping also indicates that local knowledge can help identify benefits that are relevant to community-based mangrove rehabilitation and management (Damastuti & de Groot 2019). Earlier economic analysis from Bintuni Bay similarly illustrates the value of considering links between economic and ecological conditions in mangrove conservation and management (Ruitenbeek 1994).

Blue carbon should be interpreted carefully in this review. It is relevant as a potential long-term implication of successful and socially sustained rehabilitation, but it should not be presented as an automatic result of planting (Hagger *et al.* 2024, Macreadie *et al.* 2022). Blue carbon outcomes depend on restoration success, ecological suitability, governance, monitoring, and long-term protection (Hagger *et al.* 2024, Macreadie *et al.* 2026). This interpretation keeps blue carbon in an appropriate position within the paper: it is treated as one possible restoration implication, while the core contribution remains ethnobotanical knowledge, local uses, plant parts, species selection, and community capacity.

Review-based Framework and Future Research Directions

The review-based framework in Figure 5 organizes the literature into a sequence linking local plant knowledge and values, ecological suitability, species-selection considerations, community participation, rehabilitation practice, and potential long-term outcomes. It is intended as a guide for research design and stakeholder discussion rather than as a validated predictive model.

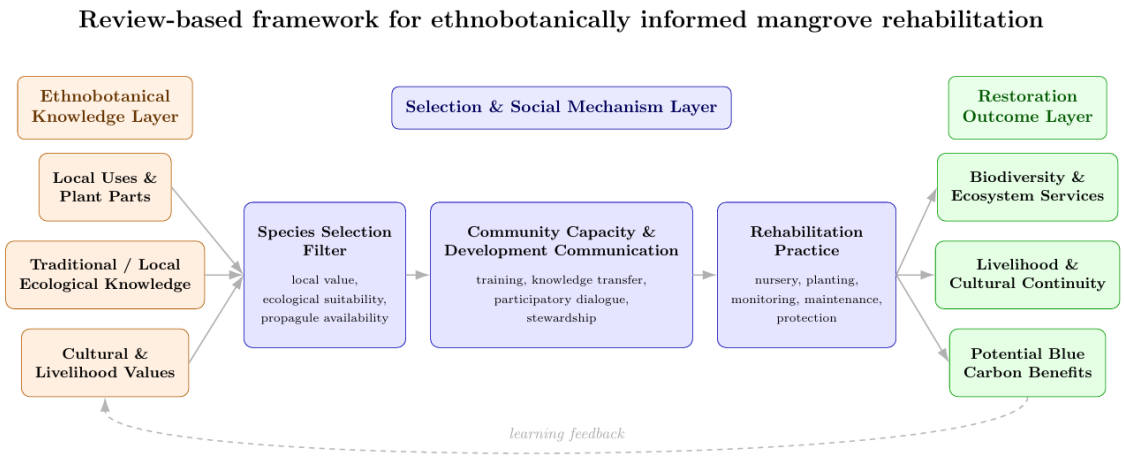

Figure 5. Review-based framework linking ethnobotanical knowledge, ecological suitability, species-selection considerations, community participation, rehabilitation practice, and potential outcomes. The framework requires field validation.

Several limitations shape the interpretation of this review. Scopus was the only bibliographic database, so relevant regional, non-indexed, and grey literature may be absent. The 2026 publication year was incomplete at the coverage cutoff. Screening and theme fields were derived from bibliographic metadata; no independent double-screening log or formal inter-rater reliability coefficient was available. Fourteen included records with mainly biochemical or medical language were checked and retained for bibliometric coverage; they were not used as direct evidence of community practice, species-selection decisions, or rehabilitation effectiveness. Five records lacked usable country affiliations, and the thematic categories were non-mutually exclusive. Country and keyword metrics reflect publication patterns rather than rehabilitation effectiveness. The species-use table is representative rather than a validated decision model. Future studies should combine multi-

database searches with transparent screening logs, public analysis code where licensing permits, and field-based measures of community preference, planting decisions, survival, maintenance, and knowledge transmission.

Conclusion

This systematic review shows that local plant knowledge, species use, and community participation are recurring themes in literature on mangrove rehabilitation. Cultural or ritual and livelihood or economic uses were the most frequently flagged categories in the empirical-oriented subset, while the keyword network showed broad connectivity but weak modular separation. These findings describe the emphasis of the indexed literature; they do not establish that local uses determine species selection or improve restoration outcomes.

For practice, ethnobotanical information can complement site-based ecological assessment by helping teams ask which species are familiar, valued, available, and feasible to maintain. Ecological suitability remains the primary condition for establishment, while community participation may support implementation and long-term stewardship. Blue carbon and other ecosystem services should be treated as potential outcomes of successful, sustained rehabilitation. Field studies are needed to test the proposed framework with direct measures of decisions, participation, survival, and maintenance.

Declarations

List of abbreviations: BC: Betweenness Centrality; BRIN: Badan Riset dan Inovasi Nasional; CBFMA: Community Based Forest Management Agreements; CI: Confidence Interval; GLM: Generalized Linear Model; HHI: Herfindahl-Hirschman Index; JFM: Joint Forest Management; LGU: Local Government Unit; NB: Negative Binomial; NDC: Nationally Determined Contributions; PFES: Payment for Forest Environmental Services; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RESEX: Extractive Reserves; SLR: Systematic Literature Review; TLS: Total Link Strength.

Ethics approval and consent to participate: Not applicable. This study is a systematic literature review and did not involve human or animal subjects.

Consent for publication: Not applicable

Availability of data and materials: The derived and pseudonymized dataset, screening documentation, R analysis code, verified analytical outputs, and Supplementary Materials supporting this study are publicly available in Zenodo: Suryanita *et al.* (2026), Version 1.0.0, doi: 10.5281/zenodo.22162599. The raw Scopus export is not redistributed because database licensing may restrict public redistribution.

Competing interests: The authors declare that they have no competing interests.

Funding: This research was supported by the Indonesia Endowment Fund for Education Agency (Lembaga Pengelola Dana Pendidikan / LPDP), Ministry of Finance, Republic of Indonesia.

Author contributions: A.S. conceptualized the study, performed data curation and thematic synthesis, and drafted the manuscript. A.A. and N.T.A. contributed to methodology validation and critical review. Y.W. contributed to data extraction and visualization. R.R. managed project administration and structural review. F.K. contributed to the knowledge-transfer and community-engagement perspective. M.A.I. recomputed the publication-trend, geographic-concentration, and keyword-network analyses and contributed to the Methods, Results, and Discussion. All authors read and approved the final manuscript.

Acknowledgements

This research was supported by master's scholarship funding from the Indonesia Endowment Fund for Education (Lembaga Pengelola Dana Pendidikan / LPDP), Ministry of Finance of the Republic of Indonesia. The scholarship recipients contributing to this study include Amelia Suryanita (NIB: 202401110200116), Rayana (NIB: 202408110906356), and Feldy Khalid (NIB: 202406110304153).

The authors sincerely acknowledge the financial support provided by the Indonesia Endowment Fund for Education Agency (LPDP). We also express our appreciation to the academic institutions of all contributing authors, particularly IPB University, the University of Bengkulu, and Universitas Sulawesi Barat, for providing the academic facilities, research environment, and institutional support that made this collaborative research possible. The authors also thank the School of Data Science, Mathematics, and Informatics (SSMI), IPB University, for technical support in the statistical bibliometric analyses.

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SUPPLEMENTARY MATERIALS

Ethnobotanical knowledge in mangrove rehabilitation: A systematic and bibliometric review of species-use patterns and community-based practice

Amelia Suryanita, Ari Anggoro, Nella Tri Agustini, Yola Wulandari, Rayana Rayana, Feldy Khalid, and Muh Akbar Idris

This document reports the detailed statistical procedures and supporting outputs referenced in the main article. The separation reduces technical density in the main text while preserving the information required to evaluate and reproduce the analyses. All results describe patterns in the reviewed literature and should not be interpreted as direct evidence of rehabilitation effectiveness.

Supplementary Methods

S1. Annual publication trend and count-model diagnostics

Annual document counts for 1991-2026 were evaluated with the Mann-Kendall test, which does not require normally distributed residuals, and Sen's slope was used to describe the median annual change. Poisson and negative binomial generalized linear models used publication year as a continuous predictor and annual count as the response. Overdispersion was assessed from the Poisson residual deviance relative to its residual degrees of freedom. Model fit was compared with Akaike's Information Criterion. The negative binomial model was retained because dispersion exceeded one and its AIC was lower. The 2026 count was treated as incomplete, and no forecast was produced.

S2. Geographic concentration and country-level association

Countries were extracted from affiliation metadata and counted in full, so a document contributed once to every identified affiliation country. Five records had no usable country field. The Gini coefficient and Herfindahl-Hirschman Index were calculated across all 87 identified countries as descriptive measures of concentration. Spearman rank correlation was used to examine the association between document count and total citations among the ten leading countries. The correlation is interpreted as a small descriptive comparison and not as evidence of causal influence.

S3. Author-keyword co-occurrence network

Author keywords were normalized for capitalization, punctuation, and close lexical variants. Keywords occurring in at least five documents were retained. Two keywords were joined by an undirected weighted edge when they occurred in the same document, and the edge weight equaled their co-occurrence frequency. Degree is reported as the proportion of other retained nodes connected to a keyword. Betweenness was calculated from weighted shortest paths, with inverse co-occurrence frequency used as edge distance. Weighted closeness, eigenvector centrality, connected components, clustering, and Louvain community membership were calculated on the same network. Community separation was evaluated with modularity, and low modularity was interpreted cautiously.

S4. Metadata-based local-use categories

Local-use flags were generated from titles, abstracts, author keywords, and index keywords. Categories were non-mutually exclusive. The main practical synthesis used 229 records not flagged as secondary literature, while the complete 262-record core was retained for comparison. Counts and shares were summarized descriptively. No equal-frequency null distribution was assumed, and no uniformity test was applied.

Supplementary Results

Supplementary Table S1. Complete annual publication counts in the 262-record core dataset.

Year	Documents	Year	Documents	Year	Documents
1991	1	2003	3	2015	3
1992	0	2004	1	2016	8
1993	1	2005	0	2017	11
1994	1	2006	5	2018	12
1995	0	2007	4	2019	12
1996	0	2008	2	2020	9
1997	1	2009	4	2021	12
1998	1	2010	2	2022	12
1999	0	2011	5	2023	29
2000	3	2012	4	2024	29
2001	1	2013	2	2025	48
2002	1	2014	3	2026	32

Supplementary Table S2. Annual trend estimates, model coefficients, and diagnostic statistics.

Analysis or parameter	Estimate	Interpretive role
Mann-Kendall tau	0.753	Direction and strength of monotonic trend
Mann-Kendall p value	<0.001	Evidence against no monotonic trend
Sen's slope	0.44 publications/year	Median annual change
Negative binomial year coefficient	0.138	Log count-rate change per year
Coefficient standard error	0.011	Uncertainty of the year coefficient
Negative binomial p value	<0.001	Evidence for a positive year coefficient
Incidence rate ratio	1.148	Multiplicative annual count-rate change
95% confidence interval for IRR	1.123-1.174	Uncertainty interval
Poisson dispersion estimate	1.504	Indicates overdispersion relative to Poisson
Poisson AIC	156.481	Model-comparison statistic
Negative binomial AIC	154.322	Lower AIC among the compared models
Negative binomial theta	18.545	Estimated dispersion parameter

Supplementary Table S3. Geographic concentration and country-level association diagnostics.

Statistic	Value	Scope
Countries identified	87	All affiliation countries in the core dataset
Records without usable country	5	Missing affiliation-country information
Internationally co-authored documents	115 (43.9%)	Documents with more than one affiliation country
Gini coefficient	0.604	Full-count contributions across 87 countries
Herfindahl-Hirschman Index	361	Full-count contributions across 87 countries
Spearman rho	-0.006	Documents versus total citations among the ten leading countries
Spearman p value	0.987	Documents versus total citations among the ten leading countries

Supplementary Table S4. Complete centrality estimates and community membership for the 25-node author-keyword network.

Keyword	Occurrences	Degree	Betweenness	Weighted closeness	Eigenvector	Community
mangrove	65	0.833	0.761	1.807	1.000	1
ecosystem service	19	0.542	0.000	1.444	0.481	2
conservation	19	0.500	0.065	1.529	0.625	1
climate change	15	0.667	0.232	1.514	0.426	3
local knowledge	13	0.333	0.065	1.331	0.297	4
biodiversity	12	0.333	0.000	1.278	0.404	1
local ecological knowledge	12	0.250	0.041	1.325	0.364	2
traditional ecological knowledge	11	0.375	0.004	1.211	0.270	3
indigenous knowledge	10	0.292	0.000	1.000	0.214	2
ethnobotany	10	0.125	0.000	1.367	0.267	1
sundarbans	9	0.500	0.005	0.983	0.233	4
ethnobiology	9	0.250	0.000	1.164	0.220	2
mangrove forest	9	0.208	0.002	0.861	0.090	2
traditional knowledge	8	0.333	0.030	1.295	0.276	1
sustainable development	6	0.292	0.000	0.721	0.132	2
cultural ecosystem services	6	0.208	0.000	0.703	0.100	2
mangrove restoration	6	0.208	0.008	0.667	0.035	4
seagrass	6	0.208	0.000	1.342	0.292	1
coastal erosion	6	0.167	0.000	0.717	0.082	4
mangrove conservation	6	0.083	0.000	0.878	0.052	3
community participation	5	0.167	0.001	0.720	0.066	4
small-scale fisheries	5	0.167	0.000	0.968	0.149	1
sundarban	5	0.167	0.000	1.015	0.187	3
wetlands	5	0.167	0.000	0.878	0.127	3
nature-based solutions	5	0.125	0.000	0.688	0.034	4

Note: Degree and betweenness are normalized. Weighted closeness was calculated from inverse co-occurrence weights and may exceed one when strongly connected keywords have mean weighted distances below one. Community numbers are labels produced by the Louvain solution and do not imply an ordinal relationship.

Supplementary Table S5. Network-level diagnostics for the author-keyword co-occurrence network.

Network statistic	Value
Nodes	25
Edges	90
Density	0.300
Average degree	7.200
Connected components	1
Largest component	25 nodes
Average weighted path length	0.992
Global clustering coefficient	0.441
Louvain communities	4
Modularity	0.166

Supplementary Table S6. Metadata-based local-use flags in the complete core and empirical-oriented subsets.

Local-use category	Core set (n=262)	Empirical subset (n=229)	Share of 380 empirical flags
Cultural or ritual	164	149	39.2%
Livelihood or economic	90	81	21.3%
Food	49	43	11.3%
Timber or construction	47	42	11.1%
Medicinal	37	28	7.4%
Fuelwood or charcoal	23	21	5.5%
Fodder	12	11	2.9%
Tannin or dye	7	5	1.3%

Note: Categories were non-mutually exclusive. The percentages use the 380 flags recorded in the 229-record empirical-oriented subset as the denominator and therefore describe representation in the reviewed metadata, not prevalence of use in coastal communities.

Supplementary data-file inventory

File	Content and role
Scopus Export Jun 14 2026.csv	Archived 365-record bibliographic export; redistribution may be restricted by Scopus licensing.
Ethnobotany Mangrove Rehabilitation.csv	Audited 262-record core dataset used for the reported analyses.
SLR PRISMA Summary.csv	Counts for identification, screening, eligibility, and inclusion.
SLR All Records with Flags.csv	Record-level screening and thematic flags.
SLR Empirical Core Subset.csv	229-record empirical-oriented subset used for the main practical-theme summary.
SLR Exclusion Reasons.csv	Record-level exclusion decisions and reasons.
SLR Local Use Category Summary.csv	Local-use counts for the complete core set.
SLR Secondary Literature Flagged.csv	Thirty-three secondary publications retained for bibliometric coverage.
SLR Supporting Ethnobotany Background.csv	Supporting records used to contextualize the ethnobotanical background.

Reproducibility note

The values in Tables S1-S6 were generated from the audited CSV files associated with the review. The Scopus search expression reported in the main Methods was confirmed against the concept blocks recorded in the review protocol and is used as the definitive documented query for this review. This clarification does not alter the audited record counts reported in the PRISMA flow.