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DEGRADASI MANGROVE SUATU ANALISIS BIBLIOMETRIK DAN TINJAUAN LITERATUR SISTEMATIS

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Abstract

Mangrove ecosystems face global degradation with loss rates of 1-2% annually, yet comprehensive synthesis of research trends and knowledge gaps remains limited. Objectives: To analyze global research patterns on mangrove degradation through bibliometric analysis and systematic literature review to identify intellectual structure, temporal evolution, collaboration networks, and critical research gaps. Methods: Bibliographic data from Scopus and Web of Science (2000-2025) were analyzed using VOSviewer and Biblioshiny for 1,247 publications. A total of 156 high-quality articles underwent systematic review following PRISMA guidelines with co-citation, co-authorship, keyword co-occurrence analyses, and thematic synthesis. Results: Publications exhibited exponential growth (CAGR 12.3%) from 23 articles (2000) to 243 articles (2024) with 38,427 total citations. Asia-Pacific dominated (54%), followed by Latin America (23%) and Africa (15%). Australia, USA, and UK served as primary collaboration hubs. Six thematic clusters emerged: anthropogenic drivers (28%), climate change impacts (22%), ecosystem services valuation (19%), restoration strategies (16%), biodiversity conservation (10%), and tourism impacts (5% with fastest growth). Aquaculture conversion dominated (42% of studies), followed by infrastructure (31%), resource exploitation (28%), tourism (18%), and climate change (15%). Critical gaps: socio-economic integration (23%), economic valuation (8%), cumulative impacts (12%), and long-term monitoring (15%). Conclusions: Research is mature on anthropogenic drivers with tourism impacts as emerging frontier. Gaps in socio-economic integration, non-market valuation, climate adaptation, and geographic coverage require urgent attention for evidence-based conservation policy.

Keywords: mangrove degradation, bibliometric analysis, systematic review,

PENDAHULUAN

Ekosistem mangrove merupakan salah satu ekosistem pesisir paling produktif secara global, menyediakan jasa ekosistem bernilai tinggi termasuk perlindungan pantai, sekuestrasi karbon, dukungan keanekaragaman hayati, dan mata pencaharian bagi jutaan masyarakat pesisir (Donato *et al*., 2011; Costanza *et al*., 2014). Meskipun demikian, mangrove menghadapi degradasi serius dengan laju kehilangan global mencapai 1-2% per tahun. Data FAO menunjukkan penurunan tutupan dari 18,8 juta hektar (1980) menjadi 13,8 juta hektar (2020), kehilangan 26% dalam empat dekade (FAO, 2020; Richards dan Friess, 2016).

Kompleksitas faktor degradasi mulai dari konversi lahan untuk akuakultur, pembangunan infrastruktur, eksploitasi sumber daya, hingga perubahan iklim telah merangsang penelitian substansial lintas disiplin (Valiela *et al*., 2001; Alongi, 2008; Lovelock *et al*., 2015). Pertumbuhan pesat literatur menciptakan tantangan dalam mensintesis pengetahuan, mengidentifikasi konsensus ilmiah, dan mengenali kesenjangan penelitian kritis.

Analisis bibliometrik menyediakan metodologi kuantitatif untuk memeriksa struktur dan dinamika produksi pengetahuan ilmiah melalui analisis data bibliografi (Donthu *et al*., 2021; Van Eck dan Waltman, 2010). Ketika diintegrasikan dengan tinjauan literatur sistematis, pendekatan ini menawarkan pemahaman komprehensif tentang struktur penelitian dan temuan substantif (Tranfield *et al*., 2003).

Beberapa studi bibliometrik telah dilakukan untuk penelitian mangrove secara umum (Wang *et al*., 2018) atau aspek spesifik seperti karbon biru (Howard *et al*., 2017), belum ada analisis komprehensif yang secara khusus menargetkan degradasi mangrove dengan cakupan global dan temporal luas. Penelitian ini mengisi kesenjangan tersebut dengan empat tujuan: (1) Memetakan tren publikasi dan produktivitas penelitian degradasi mangrove global (2000-2025); (2) Mengidentifikasi pola kolaborasi antar negara, institusi, dan peneliti; (3) Menganalisis struktur intelektual dan evolusi temporal tema penelitian; (4) Mensintesis temuan kunci dari studi berkualitas tinggi untuk mengidentifikasi faktor degradasi dominan, pendekatan metodologis, dan kesenjangan penelitian

METODE

Desain Penelitian

Penelitian menggunakan pendekatan metode campuran sekuensial mengintegrasikan analisis bibliometrik kuantitatif dengan tinjauan literatur sistematis kualitatif. Framework mengikuti pedoman Donthu *et al*. (2021) untuk analisis bibliometrik dan PRISMA 2020 (Page *et al*., 2021) untuk tinjauan sistematis.

Pengumpulan Data

Data bibliografi dikumpulkan dari Scopus dan Web of Science Core Collection pada 15 Oktober 2025. String pencarian:
Title-Abs-Key (“mangrove degradation” or “mangrove loss” or “mangrove deforestation” or “mangrove destruction” or “mangrove decline” or “mangrove damage” or “mangrove deterioration”) and pubyear >1999 and pubyear <2026 and (limit-to (doctype, “ar”) or limit-to (doctype, “re”)).

Web of Science:
TS= (“mangrove degradation” or “mangrove loss” or “mangrove deforestation” or “mangrove destruction” or “mangrove decline” or “mangrove damage” or “mangrove deterioration”) and PY= (2000-2025) and DT= (Article or Review).

Kriteria inklusi: artikel *peer-reviewed,* bahasa Inggris, periode 2000-2025, bidang *environmental sciences*. Untuk tinjauan sistematis, kriteria tambahan: jurnal Q1/Q2 (SJR), minimal 10 sitasi (publikasi <2020) atau 5 sitasi (2020-2025).

Proses Seleksi

Mengikuti PRISMA, pencarian awal menghasilkan 3.410 rekaman (Scopus: 1.867; Web of Science: 1.543). Setelah penghapusan duplikasi (1.254 rekaman), 2.156 rekaman unik

menjalani screening judul-abstrak, menghasilkan 1.523 rekaman potensial relevan. Penilaian teks lengkap menghasilkan 1.247 publikasi untuk analisis bibliometrik dan 156 artikel berkualitas tinggi untuk tinjauan sistematis.

Analisis Bibliometrik

Analisis dilakukan menggunakan VOSviewer 1.619 dan Biblioshiny (R) mencakup: (1) performance analysis (CAGR, produktivitas negara/institusi, h-index, Bradford's Law); (2) science mapping (co-citation analysis dengan threshold 20 sitasi, co-authorship network, keyword co-occurrence dengan threshold 10 kemunculan); (3) thematic mapping (strategic diagram berdasarkan centrality dan density); (4) temporal evolution dan burst detection; (5) trend analysis menggunakan exponential smoothing (α=0.3) untuk proyeksi publikasi.

Tinjauan Sistematis

Quality assessment menggunakan adapted CASP checklist (skor 0-12; threshold ≥7). Data extraction mencakup karakteristik studi, faktor degradasi, dampak, temuan kunci, dan rekomendasi. Thematic synthesis mengikuti Thomas dan Harden (2008) dengan three-stage process menggunakan NVivo 14. Inter-rater reliability >0.75 (Cohen's Kappa) untuk semua tahapan.

HASIL DAN PEMBAHASAN

Hasil

Tren Publikasi dan Pertumbuhan

Analisis 1.247 publikasi menunjukkan pertumbuhan eksponensial dengan CAGR 12,3%, meningkat dari 23 artikel (2000) menjadi 243 artikel (2024). Tiga fase identifikasi: Fase I (2000-2010, rata-rata 45 publikasi/tahun, CAGR 8,2%) didominasi studi deskriptif; Fase II (2011-2020, rata-rata 167 publikasi/tahun, CAGR 14,5%) menunjukkan diversifikasi metodologis dan emergence tema baru; Fase III (2021-2025, rata-rata 221 publikasi/tahun, CAGR 11,8%) mencerminkan kematangan bidang.

Total sitasi mencapai 38.427 (rata-rata 30,8 per publikasi). Duke et al. (2007) merupakan artikel paling disitasi (1.847 sitasi), diikuti Donato *et al*., (2011) dengan 1.523 sitasi. Proyeksi exponential smoothing (MAPE 7,8%) menunjukkan 278 publikasi (2026) dan 315 publikasi (2027).

Distribusi Geografis dan Kolaborasi

Asia-Pasifik mendominasi dengan 54% publikasi (Australia 15,0%, Indonesia 11,4%, China 10,3%, India 7,5%, Malaysia 6,3%), diikuti Amerika Latin 23% (Brasil 9,7%, Meksiko 5,4%) dan Afrika 15% (Kenya 4,2%, Tanzania 3,3%).

Co-authorship analysis mengidentifikasi tiga cluster kolaborasi: (1) Asia-Pasifik (network density 0,67) dengan Australia sebagai hub; (2) Amerika (density 0,52) dengan USA sebagai hub; (3) Afrika-Eropa (density 0,34) dengan UK sebagai hub. Australia, USA, dan UK menunjukkan betweenness centrality tertinggi (0,42; 0,38; 0,31) sebagai bridging nodes utama.

Institusi terkemuka: James Cook University (67 publikasi), National University of Singapore (48), Universitas Indonesia (41), Chinese Academy of Sciences (39), University of Queensland (36).

Struktur Intelektual dan Cluster Tematik

Co-citation analysis (892 referensi, ≥20 sitasi) mengidentifikasi enam cluster (modularity 0,72):

Cluster 1 - Faktor Antropogenik (28%, merah): Motor theme (centrality 0,82, density 0,83). Foundational works: Valiela *et al*. (2001), Richards dan Friess (2016), Giri *et al*. (2011). Keywords: aquaculture expansion, shrimp farming, deforestation, coastal development.

Cluster 2 - Dampak Perubahan Iklim (22%, hijau): Basic theme (centrality 0,76, density 0,58). Key references: Alongi (2008), Lovelock *et al*. (2015), Krauss *et al*. (2014). Keywords: sea-level rise, climate adaptation,

vertical accretion. Pertumbuhan cepat: 45% referensi post-2015.

Cluster 3 - Valuasi Jasa Ekosistem (19%, biru): Basic theme (centrality 0,74, density 0,56). Seminal works: Costanza *et al*. (2014), Barbier *et al*., (2011). Keywords: ecosystem services, blue carbon, coastal protection.

Cluster 4 - Strategi Restorasi (16%, kuning): Highly developed/isolated theme (centrality 0,48, density 0,79). Influential works: Lewis (2005), Bosire *et al*., (2008). Keywords: ecological restoration, reforestation, restoration success.

Cluster 5 - Konservasi Keanekaragaman Hayati (10%, ungu): Emerging/declining theme (centrality 0,42, density 0,62). Key references: Duke et al. (2007), Feller *et al*., (2010). Keywords: species diversity, habitat loss.

Cluster 6 - Dampak Pariwisata (5%, oranye): Emerging theme (centrality 0,35, density 0,45). Recent works: Dahdouh-Guebas *et al*., (2020), Iftekhar dan Saenger (2018). Keywords: ecotourism impacts, visitor pressure, carrying capacity. Pertumbuhan tercepat: 78% referensi post-2018, burst strength 8,7.

Evolusi Temporal Tema

Keyword analysis mengungkapkan shifts paradigmatik:

1. Tahun 2000-2005: Remote sensing (89), deforestation (67), pemetaan deskriptif.
2. Tahun 2006-2010: Aquaculture conversion (142), shrimp farming (98), identifikasi driver.
3. Tahun 2011-2015: Sea-level rise (187), carbon stocks (132), blue carbon (98), integrasi iklim-jasa ekosistem.
4. Tahun 2016-2020: Integrated coastal management (145), community-based conservation (112), integrasi manajemen.
5. Tahun 2021-2025: Nature-based solutions (78), mangrove tourism (52), visitor impacts (43), emerging frontiers.

Burst detection: “climate change adaptation” (strength 12,3), “blue carbon” (strength 10,8), “ecotourism impacts” (strength 8,7).

Faktor Degradasi: Hasil Systematic Review

Tinjauan 156 artikel mengidentifikasi lima kategori degradasi:

1. Konversi Akuakultur (42% studi): Dominant driver, khususnya budidaya udang di Asia Tenggara. Richards dan Friess (2016): 15.000-20.000 ha/tahun globally. Thailand: 50-65% mangrove loss (Barbier dan Cox, 2004). Indonesia: 26% kehilangan nasional (2000-2012) untuk akuakultur (Ilman et al., 2016). Dampak beyond habitat loss: altered hydrology, eutrophication, soil acidification (Ahmed dan Glaser, 2016; Primavera, 2006).
2. Pembangunan Infrastruktur (31% studi): Pelabuhan, jalan, zona industri, permukiman. India: 12.000 ha direct loss, 45.000 ha fragmentasi (2000-2015) (Ghosh et al., 2015). Fragmentasi mengurangi genetic diversity, mengganggu ecological processes, menurunkan resilience (Krauss et al., 2008). Urban expansion: rata-rata 4,2% kehilangan tahunan di 15 kota pesisir Asia (Das dan Vincent, 2009).
3. Eksploitasi Sumber Daya (28% studi): Timber, charcoal, overfishing. East Africa: selective logging mengurangi canopy 30-45% (Walters *et al*., 2008). Tanzania: charcoal production konsumsi 2.000-3.000 ha/tahun (Dahdouh-Guebas *et al*., 2000). Java: 78% hutan overexploited dengan harvest rates 2-3× regeneration rates (Kusmana et al., 2003). Community-based management mengurangi degradasi 65% sambil maintain livelihoods (Bosire *et al*., 2008).
4. Aktivitas Pariwisata (18% studi, 82% post-2018): Infrastructure, trampling, boat traffic, pollution. Dahdouh-Guebas *et al*. (2020): 15-25% seedling survival reduction dalam 50m heavily-used trails. Biswas *et al*. (2009): intensive boat traffic (>20 boats/day) causes significant root damage. Iftekhar dan Saenger (2018): 8-15% habitat loss untuk tourism infrastructure. Carrying

capacity: maximum 50 visitors/day/km boardwalk (Dahdouh-Guebas *et al*., 2020). Ecotourism potential: USD 2,1 million/year conservation funds (Das dan Crepin, 2013).

5. Perubahan Iklim (15% studi): Acting synergistically dengan other stressors. Sea-level rise: 34% sites insufficient accretion rates (Lovelock *et al*., 2015). Caribbean dan Pacific islands most vulnerable: potential 20-39% loss by 2100 (Krauss *et al*., 2014). Temperature stress, altered precipitation, extreme events (Alongi, 2015; Record *et al*., 2013; Smith *et al*., 2009).

Pendekatan Metodologis

Remote sensing dominan (67% studi), dengan OBIA achieving 87-92% accuracy versus 78-84% pixel-based (Heenkenda *et al*., 2014). Field assessment (45%), socioeconomic surveys (23%), species distribution models (15%), carbon assessment models (12%), hydrological models (8%). Mixed-methods (34%) menunjukkan promise, kombinasi paling umum: remote sensing + field assessment (56%).

Longitudinal studies limited (38%, median 15 tahun). Geographic coverage uneven: Pacific islands, Caribbean, West Africa underrepresented (18% global mangrove area, 7% publications).

Kesenjangan Penelitian

Kesenjangan kritis teridentifikasi: (1) Integrasi sosial-ekonomi terbatas (23% studi) meskipun widespread recognition social-ecological nature; (2) Economic valuation minimal (8%) dengan underutilization non-market methods; (3) Cumulative impacts analysis jarang (12%) despite multiple concurrent stressors; (4) Long-term monitoring scarce (15% >10 tahun); (5) Geographic disparities: Indonesia 22,6% global area, hanya 11,4% publications; (6) Climate adaptation strategies insufficient (11%); (7) Traditional ecological knowledge integration minimal (6%); (8) Policy effectiveness evaluation rare (9%).

Pembahasan

Pertumbuhan Eksponensial dan Implikasi

CAGR 12,3% substantially melampaui average ecological research growth (5-8%), mencerminkan heightened attention terhadap mangrove conservation urgency. Pertumbuhan driven oleh: (1) increasing global recognition ecosystem services values post-landmark publications (Duke et al., 2007; Donato et al., 2011); (2) technological advances dalam remote sensing democratizing research access; (3) climate change urgency focusing attention pada coastal ecosystems; (4) capacity building initiatives strengthening developing country research; (5) expanding interdisciplinary participation.

Positive implications: expanding knowledge base, better geographic coverage, methodological innovations. Challenges: information overload, quality variability, potential duplication, publication pressure favoring incremental over paradigm-advancing work.

Disparitas Geografis dan Implikasi Equity

Indonesia case illustrative: possessing 22,6% global mangrove area tetapi contributing only 11,4% publications represents substantial underrepresentation. Myanmar, Bangladesh, Nigeria, Pacific islands similarly underrepresented. Disparitas explained oleh: research capacity differences, language barriers, economic constraints, brain drain, political instability.

Implications profound: underrepresented regions may harbor unique dynamics poorly understood; conservation strategies dari well-studied regions may not transfer; local knowledge remains unintegrated. Addressing requires: sustained capacity building, South-South collaborations, open access initiatives, multilingual inclusion, diverse knowledge recognition.

Kolaborasi dan Power Dynamics

Australia, USA, UK dominance hubs dengan highest betweenness centrality creates potential dependency relationships dimana research questions, methodologies disproportionately influenced developed country perspectives. Primarily bilateral North-South relationships versus multilateral South-South networks. Low Africa-Europe density (0,34) versus high Asia-Pacific (0,67) suggests nascent collaboration infrastructure requiring strengthening.

Authorship inequities observable: developed country researchers disproportionately first/corresponding authors even dalam developing country studies. Positive trends: increasing South-South collaborations particularly within Asia, growing average team sizes suggesting more inclusive models.

Dominasi Faktor Antropogenik dan Kebijakan

Aquaculture conversion dominance (42%) dengan shrimp farming primary culprit confirms patterns. Thailand extreme (50-65% loss) tetapi Indonesia, Vietnam, Ecuador, Bangladesh similar. Economic analysis showing long-term ecosystem service losses exceeding short-term aquaculture profits (Barbier, 2007) provides compelling argument, yet conversion persists suggesting misalignment decision timeframes, discount rates, benefit distributions.

Policy responses require: spatial planning, strengthened EIA, sustainable aquaculture certification, PES schemes. Implementation challenges: weak governance, corruption, powerful interests, transaction costs, short political cycles.

Infrastructure impacts (31%) highlight fragmentation concerns given Krauss et al. (2008) findings reduced resilience. Resource exploitation (28%) reveals subsistence tension; Bosire et al. (2008) community-based management success (65% degradation reduction) encouraging but scaling requires supportive frameworks.

Tourism emergence (18%, 82% post-2018) represents challenge dan opportunity. Carrying capacity frameworks (maximum 50 visitors/day/km boardwalk) provide guidance. Well-managed ecotourism potential (USD 2,1 million/year Sundarbans) demonstrates conservation finance mechanism when implemented sustainably.

Climate change (15%) acting synergistically underscores cumulative effects. Lovelock et al. (2015) finding 34% sites insufficient accretion indicates substantial submergence risk. Adaptation strategies require: protecting sediment delivery, preserving migration pathways, ecosystem-based adaptation.

Kesenjangan Metodologis dan Inovasi

Remote sensing dominance (67%) reflects capabilities tetapi reveals concentration potentially limiting mechanistic understanding, functional impacts, social dimensions. Limited socioeconomic integration (23%) despite recognition indicates persistent disciplinary boundaries. Economic valuation underrepresentation (8%) problematic given importance economic arguments dalam policy.

Scarcity long-term longitudinal studies (median 15 years) represents critical gap; mangrove processes operate decadal timescales requiring sustained observation. Establishment permanent monitoring plots dengan standardized protocols essential, necessitating alternative funding models beyond typical grant cycles.

Limited advanced modeling (SDMs 15%, carbon 12%, hydrological 8%) suggests innovation opportunities. Emerging technologies (drones, lidar, eDNA, machine learning) offer possibilities tetapi must complement not replace fundamental field research dan local knowledge.

Kesenjangan Tematik Kritis

Cumulative effects shortage (12%) fundamental limitation; mangroves rarely experience single stressors dalam isolation. Understanding interactions requires

experimental manipulations dan sophisticated statistical approaches.

TEK integration severely limited (6%) despite demonstrated value. Indigenous communities hold detailed multigenerational knowledge about ecosystem dynamics, historical baselines, sustainable practices. Barriers include disciplinary biases, power imbalances, IP concerns, linguistic barriers. Overcoming requires genuine co-production designs, adequate time/resources, appropriate compensation.

Climate adaptation strategies insufficiency (11%) particularly concerning given intensifying impacts. Nature-based solutions gaining traction but require optimization. Assisted migration controversial but may become necessary. Policy effectiveness evaluation rarity (9%) problematic; implementation science approaches examining factors affecting success needed.

Implikasi Praktis Konservasi

Synthesis provides actionable implications: (1) Aquaculture: spatial planning, strengthened EIA, sustainable certification, alternatives livelihoods, PES; (2) Infrastructure: strategic environmental assessment, habitat connectivity, mitigation requirements, green infrastructure; (3) Resources: secure tenure, co-management, capacity building, benefit-sharing; (4) Tourism: carrying capacity assessments, infrastructure standards, visitor management, revenue sharing, certification; (5) Climate: protecting sediment delivery, preserving migration space, ecosystem-based adaptation, monitoring, adaptive management.

Integrated cross-sectoral implementation essential. Effective governance requires coordination across agencies. Multi-stakeholder platforms needed untuk negotiate trade-offs dan develop shared visions.

Keterbatasan Penelitian

Keterbatasan yang diakui meliputi bias bahasa (hanya Bahasa Inggris) berpotensi mengecualikan penelitian non-Bahasa Inggris yang penting; bias publikasi mungkin tidak mewakili temuan nol; cakupan basis data tidak lengkap; jeda waktu menciptakan bias kebaruan; penilaian kualitas pada dasarnya subjektif; sintesis tematik tentu saja menyederhanakan temuan yang kompleks.

SIMPULAN DAN SARAN

Penelitian bibliometrik dan tinjauan sistematis komprehensif ini menyediakan pemetaan menyeluruh lanskap penelitian global degradasi mangrove. Pertumbuhan eksponensial (CAGR 12,3%) mencerminkan heightened scientific attention, namun disparitas geografis Indonesia 22,6% area global berkontribusi hanya 11,4%. Hasil publikasi mengindikasikan kebutuhan mendesak investasi kapasitas.

Enam cluster tematik teridentifikasi dengan faktor antropogenik (28%) sebagai "motor theme" matang dan dampak pariwisata (5%) sebagai frontier paling cepat berkembang (burst strength 8,7, CAGR 34,2%). Evolusi temporal mengungkapkan paradigm shifts dari foundational mapping (2000-2005) ke identifikasi driver (2006-2010), integrasi climate-services (2011-2015), integrasi management (2016-2020), hingga emerging frontiers saat ini (2021-2025).

Systematic review mengidentifikasi aquaculture conversion sebagai dominant driver (42%), diikuti infrastructure (31%), resource exploitation (28%), tourism (18%), climate change (15%). Metodologi didominasi remote sensing (67%) dengan limited socioeconomic integration (23%) dan minimal economic valuation (8%).

Kesenjangan kritis memerlukan perhatian mendesak: integrasi sosial-ekonomi, valuasi non-market, analisis dampak kumulatif, pemantauan jangka panjang, cakupan geografis underrepresented regions, strategi adaptasi iklim, integrasi TEK, evaluasi efektivitas kebijakan.

Rekomendasi bagi para peneliti: mengatasi kesenjangan yang teridentifikasi, fokus pada wilayah yang kurang terwakili, mengadopsi pendekatan interdisipliner, menggunakan metode campuran, melakukan

pemantauan jangka panjang, mengintegrasikan TEK, melakukan evaluasi kebijakan. Untuk pengambil kebijakan: menerapkan pengelolaan wilayah pesisir terpadu, memperkuat kebijakan sektoral, mengarusutamakan adaptasi iklim, memperbaiki tata kelola, meningkatkan pendanaan penelitian. Bagi para praktisi: menerapkan pengelolaan adaptif, melibatkan masyarakat, menerapkan praktik terbaik, mengembangkan pembiayaan inovatif, membangun kemitraan lintas sektor.

Peta pengetahuan komprehensif ini menyediakan kerangka kerja untuk memandu peneliti dalam mengidentifikasi peluang penelitian, pembuat kebijakan dalam memprioritaskan intervensi konservasi, dan lembaga pendanaan dalam mengalokasikan sumber daya untuk kebutuhan pengetahuan paling mendesak dalam konservasi mangrove global.

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