

TRENDS IN FOREST CONSERVATION RESEARCH IN ACEH PROVINCE, INDONESIA THROUGH 2023: A BIBLIOMETRIC ANALYSIS

Durrah Hayati^{1*}, Yusuf B. Samsudin², Fahmy Armanda³, Virda Zikria⁴, Ali M. Muslih¹, Sarah Andini⁵, and Syed A. Rahman⁶

¹Department of Forestry, Faculty of Agriculture, Syiah Kuala University, Aceh 23111, Indonesia

²Wildlife Conservation Research Unit (WildCRU), Department of Biology, University of Oxford, United Kingdom

³Department of Biology Education, Faculty of Teacher Training and Education Science, Universitas Samudera, Aceh, Indonesia

⁴Department of Agribusiness, Faculty of Agriculture, Syiah Kuala University, Aceh, Indonesia

⁵Research Center for Ecology and Ethnobiology, National Research and Innovation Agency, Republic of Indonesia Jl. Raya Jakarta-Bogor Km.46, Cibinong, Bogor, West Java, Indonesia, 16911

⁶Institute of Ecology and Key Laboratory for Earth Surface Processes of the Ministry of Education, College of Urban and Environmental Science, Peking University, Beijing 100871, China

Received: 5 January 2024 , Revised: 4 November 2024, Accepted: 5 November 2024

TRENDS IN FOREST CONSERVATION RESEARCH IN ACEH PROVINCE, INDONESIA THROUGH 2023: A BIBLIOMETRIC ANALYSIS. Forestry research is crucial for forest conservation, sustainable resource utilization, informing policy, promoting development, and enhancing ecosystem understanding. This research is vital for creating policies that ensure forest conservation and support local livelihoods, especially as forests face depletion and degradation threats. Aceh, which contains the largest remaining forests in Sumatra, plays a crucial role in both local and global conservation. Therefore, understanding Aceh's forest conservation research is the first step to improve conservation practices. This study employs a bibliometric analysis of forest conservation research in Aceh, using Bibliometrix and Biblioshiny to analyze trends. Using the Scopus database, 354 relevant articles were identified. The analysis shows publication patterns, including document types, article sources, and research affiliations with Syiah Kuala University being the primary contributor. The study also examined the knowledge structure through keyword frequency, trends, and keyword co-occurrences. Results show peer-reviewed journal articles and conference papers as the main publication types, with increased publications post-2005 due to Aceh's post-war political stabilization. Keywords, i.e. 'forestry', 'conservation', 'fisheries', and 'ecosystem' were found important. Topic trends revealed interest in forest management, ecosystem services, and disaster-related terms at post-2004 tsunami. Co-occurrence network analysis identified six main keyword clusters, i.e. biodiversity, conservation, land use and land cover change, and sustainable development.

Keywords: Forest conservation, bibliometric analysis, research trend, Aceh

TREN PENELITIAN DENGAN TEMA KONSERVASI HUTAN DI PROVINSI ACEH, INDONESIA HINGGA TAHUN 2023: ANALISIS BIBLIOMETRIK. Penelitian di bidang kehutanan sangat penting dalam konservasi hutan, pemanfaatan sumber daya yang berkelanjutan, memberikan informasi kebijakan, mendorong Pembangunan, dan meningkatkan pemahaman ekosistem. Penelitian-penelitian tersebut sangat penting untuk menciptakan kebijakan terhadap konservasi hutan dan mendukung penghidupan Masyarakat lokal, terutama karena hutan saat ini menghadapi ancaman deforestasi dan degradasi. Aceh, dengan sisa hutan terluas di Pulau Sumatera, memainkan peran penting dalam konservasi di tingkat lokal maupun secara global. Oleh karena itu, memahami lanskap penelitian konservasi di Aceh merupakan langkah pertama untuk meningkatkan praktik-praktik konservasi. Penelitian ini menerapkan analisis bibliometrik terhadap penelitian konservasi hutan di Aceh dengan menggunakan Bibliometrix dan Biblioshiny untuk menganalisis tren. Sejumlah 354 artikel relevan dari database Scopus berhasil diidentifikasi. Analisis menunjukkan pola

*Corresponding author: durrah@usk.ac.id

publikasi meliputi jenis dokumen, sumber artikel, dan afiliasi penelitian. Studi ini juga menganalisis struktur pengetahuan melalui kata kunci yang sering digunakan, tren topik, dan kata kunci terbaru. Hasil penelitian menunjukkan publikasi utama didominasi oleh artikel proceeding dan jurnal peer review, dimana jumlah dokumen publikasi meningkat pesat pasca tahun 2005 karena adanya stabilisasi politik pasca perang sipil. Kata kunci seperti “kebutanan”, “konservasi”, “perikanan”, dan “ekosistem” merupakan kata kunci penting. Analisis tren topik menunjukkan kemunculan ketertarikan terhadap topik pengelolaan hutan, jasa ekosistem, dan istilah-istilah terkait bencana pasca tsunami tahun 2004. Hasil analisis co-occurrences network mengidentifikasi 6 klaster kata kunci utama, yang berfokus pada keanekaragaman hayati, konservasi, penggunaan lahan dan perubahan tutupan lahan, serta pembangunan berkelanjutan.

Kata kunci: Konservasi hutan, analisis bibliometrik, tren penelitian, Aceh

I. INTRODUCTION

Forestry research is essential for sustainable forest resource use, informing policies, and understanding ecosystems. Initially, it focused on tree species and timber harvesting, but it has since expanded to include biodiversity conservation, sustainable management, and multi-use forest land integration (Teeguarden, 1979). This research informs policies that protect forests while supporting those dependent on them, addressing threats like depletion and degradation (Tewari, 1994). Additionally, forest conservation research promotes sustainable development by enhancing productivity and reversing negative trends, including genetic resource loss, through improved techniques and technologies (Tewari, 1994). The focus of forest research globally has seen a shift in focus from genetic and biomedical studies to ecological studies of key species and habitats (Prins & Wind, 1993). In Indonesia, this shift has been influenced by the country's economic restructuring and the need to address deforestation and forest degradation (Wardojo & Masripatin, 2002). The country has made significant efforts to reduce deforestation, including a moratorium on permitting primary natural forests and peatlands, and the development of sustainable forest management policies (Nugroho et al., 2023). However, challenges remain, including the need for a more participatory approach to forest management and the control of illegal activities (Alam et al., 2019).

Indonesian forest policy has seen major changes, particularly in forest and biodiversity conservation. Initially, the forest sector in Indonesia was non-commercial, but it evolved to become vital to the national economy by the 1970s. However, rapid forest degradation followed, due to limited regeneration efforts and land-use policy changes for settlement and agriculture (Wardojo & Masripatin, 2002). In response, the forestry sector reformed to address environmental challenges. By 2003, the Ministry of Forestry prioritized conserving remaining forests and rehabilitating degraded lands, marking a shift toward sustainability and conservation in policy (Wardojo & Masripatin, 2002). The changes of concern in forest conservation policies in Indonesia have been met with various responses from the research and scientific community. For instance, some researchers emphasize the significance of research on the rehabilitation of degraded forest land and conservation of remaining forest (Wardojo & Masripatin, 2002), and some others highlight the need for a more integrated approach that links remote sensing, ecological, and social science research such as community involvement, conservation funding, corruption, and global shift towards neoliberalism to better understand and manage the forests (Adnan & Dadi, 2023; Gellert, 2005; Sánchez-Azofeifa et al., 2005).

Research has shown that the costs of deforestation in Aceh are high as it has forests with high ecosystem services value (Cochard,

2017). As the region with the most remaining forest in Sumatra, Aceh plays a crucial role in forest conservation for both local and global ecosystems. Aceh is home to rich and diverse forest ecosystems, including tropical rainforests and peatlands, which harbor a wide array of unique plant and animal species (Gumay et al., 2019). The Gunung Leuser National Park (GLNP) in Aceh serves as a crucial refuge for over 50% of Sumatra's plant diversity, with around 10,000 plant species, including 17 endemic genera, 201 mammal species, and 580 bird species, including 21 endemic species. The GLNP is vital for preserving the biodiversity of lowland forests in Southeast Asia, which are rapidly disappearing (Cochard, 2017; IUCN World Heritage, 2020). Protecting and conserving Aceh's forest is therefore paramount to preserving biodiversity, mitigating climate change, and ensuring the long-term ecological integrity of the region.

More than 58% of this province's land is forested area, of which 50.2% is protected forest and almost 20% belong to a national park and wildlife reserve (Mundzir et al., 2023). This is partly because of the province's isolated and distinctive geography and history of open conflict that raged in Aceh from the 1970s until 2004 which has left the forest in a near-pristine condition for at least 35 years (Cochard, 2017). According to Cochard (2017) despite being home to valuable tropical rainforest, immense biodiversity, and rare wildlife, Aceh does not seem to lead a good path towards sustainable practices in the long-term, proven by many cases of environmentally destructive natural resource extraction practices, for instance, conversion of peatlands into oil palm plantations. This condition emphasizes the need for effective conservation approaches that can be achieved through effective and well-informed forest conservation policies.

Understanding the scientific landscape of forest conservation research in Aceh can be the first step to developing and implementing better practices in forest conservation

(Cochard, 2017; Linkie et al., 2013). Therefore, this research seeks to systematically review and map out earlier studies on forest conservation in Aceh, concentrating on bibliographic trends and the primary topics previously investigated. This study introduces the first bibliometric analysis which focuses on forest conservation in Aceh. Mapping past studies such as in bibliometrics analysis can provide insights into key trends and gaps in a specific scope and study area. This method can identify influential publications, authorship patterns, co-citation networks, thematic areas, key research themes, and emerging themes (Bullock & Lawler, 2015; Szomszor et al., 2021). This information can provide direction for potential future research and encourage researchers to conduct more targeted and impactful research in the future to collectively help shape better forest management and policy in Aceh. Therefore, in this study, we conduct a bibliometric analysis of forest conservation research in Aceh, Indonesia. We use bibliometric analysis because of its ability to systematically evaluate and quantify the impact of research publications, identify trends and patterns in scientific literature, assess the productivity and influence of researchers and institutions, and facilitate the discovery of key research areas, research gaps, and emerging topics within forest conservation field in Aceh.

II. METHODS

This study utilizes the Scopus database as the primary data source. Scopus is the largest database of scientific documents in the world, with over 87 million items from more than 7,000 publishers in 105 countries, including more than 17 million author profiles (Elsevier, 2023). The dataset was converted into BibTex format and then imported into Biblioshiny for analysis using the R 4.3.0 programming language. In this study, we used the Bibliometrix and Biblioshiny software packages to analyse and visualise the status of research and research trends in the forest conservation fields in Aceh Province, Indonesia.

The keyword search used to extract data from the Scopus database was: “Forest” OR “Forestry” OR “Hutan” OR “Kehutanan” AND “Conservation” OR “Konservasi” AND “Aceh” OR “Bener Meriah” OR “Gayo Lues” OR “Pidie” OR “Simeulue” OR “Bireuen” OR “Nagan Raya” OR “Pidie Jaya” OR “Sabang” with a publication time range of all-time until April 2023, which is the time when the data extraction was conducted. These keywords include the primary term ‘forest’ and ‘conservation’ in both English and Indonesian, along with the names of districts within Aceh Province that do not contain the word ‘Aceh’ such as ‘Bireun’. Names of districts that do contain the word ‘Aceh’, such as ‘Aceh Besar’, are excluded from the keywords because they are already represented by the term ‘Aceh’. This is to avoid repetition in keywords. The inclusion of specific district names aims to enhance the

retrieval of region-specific research related to Aceh Province. A total of 354 publications were obtained and analysed using Bibliometrix and Biblioshiny.

III. RESULT AND DISCUSSION

A. Bibliography Pattern of Scientific Publications on Forest Conservation in Aceh

A.1. Number of publications

The search conducted in the Scopus database based on the keyword string yielded a total of 354 articles related to forest and conservation studies in Aceh. Several types of documents were found, including peer-reviewed journal articles comprising 47%, followed by conference papers at 45%. The remaining documents consisted of book chapters (3%), conference reviews (2%), and other document types (3%)

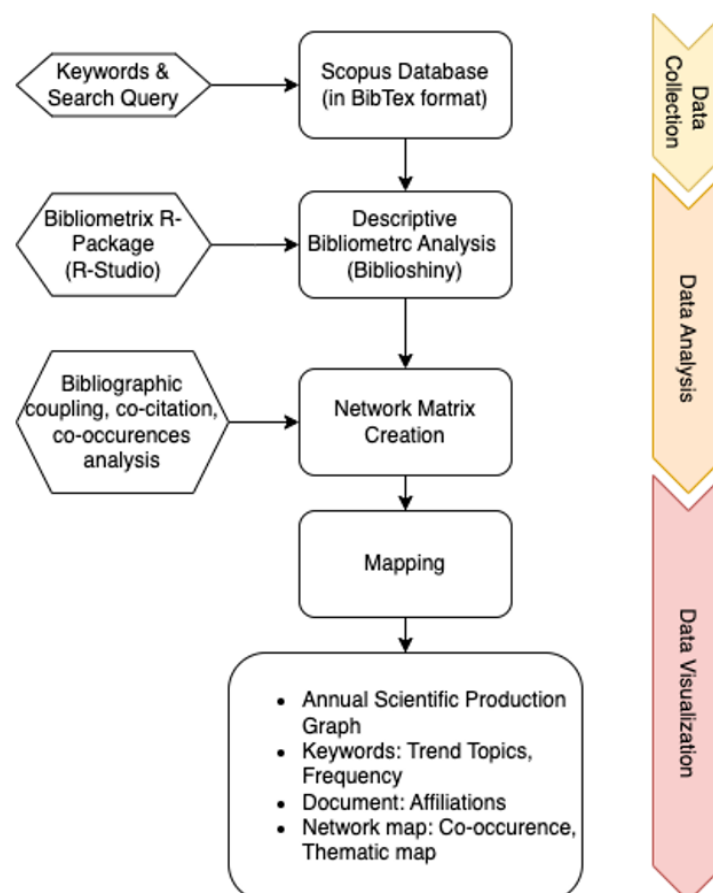


Figure 1. Data analysis workflow

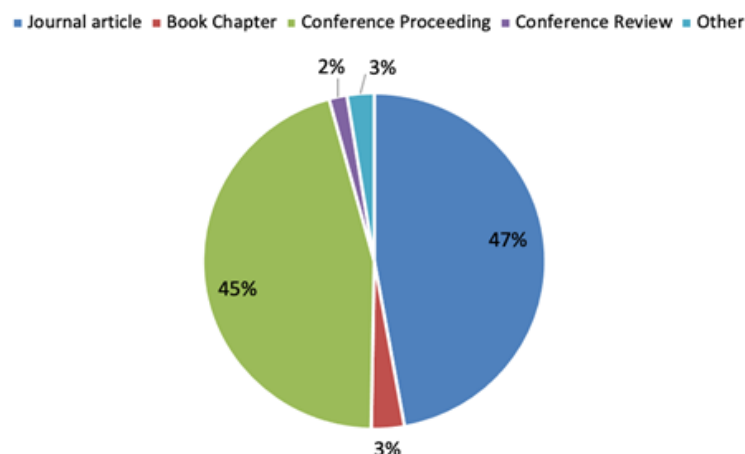


Figure 2. Elevation and land cover map of Portugal (Meneses et al., 2018).

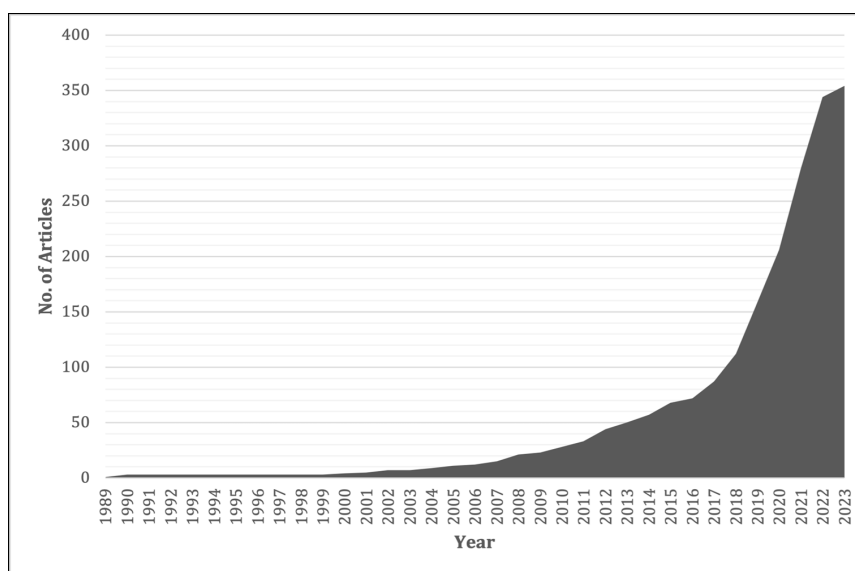


Figure 3. Annual publication volume of forest conservation research

such as editorials and review letters (Figure 2).

Based on the results of bibliometric analysis (Figure 3), it is known that research on forest conservation in Aceh indexed in Scopus began in 1989. Studies on forest conservation in Aceh were absent from the record between 1991 to 1999. The database continued the record with an insignificant number of publications in 2000. The momentum of the increase in the number of publications started in 2007 when the number of publications increased significantly compared to previous years. In the following years, there was a slow increase in the number of scientific publications until

2016, with an average of 6 articles per year. The number of scientific publications has sharply increased since 2017, reaching its peak in 2021 with 74 scientific publications related to forest conservation in Aceh.

The substantial increase in forest conservation publications in 2007 reflects a growing interest among researchers in this field. Most publications identified in the Scopus database are scientific articles and seminar papers, which show a primary focus on empirical research and data analysis. Notably, the peak publication year in 2021 suggests that interest in forest conservation in Aceh

has only recently gained momentum and is likely to continue expanding, driven by rising awareness of forests' role in climate change mitigation, global funding, and government-backed conservation initiatives (Bishop et al., 2006; Vincent et al., 2014). Furthermore, an analysis of publication trends reveals the influence of political conditions on scientific activity. The limited publications from 1989 to 2005 coincide with Aceh's civil war, lasting from the 1970s until a peace agreement in 2005 (Lassa, 2010). The post-war period saw a rise in publications beginning in 2007, suggesting a link between stability and research advancement in Aceh. Fiialka (2022) supports this correlation, showing that war hinders research by causing psychological strain, funding challenges, loss of relevance, disrupted scientific networks, and obstacles in fieldwork, factors likely impacting Aceh's isolated and restricted access to research support during the conflict. Additionally, forest conservation research may have been deprioritized in favour of urgent social issues amid the insurgency.

A.2. Main publication platforms

The majority (153 articles) of the scientific publications were published in various conferences in collaboration with the IOP Conference Series: Earth and Environmental

Science, Journal of Physics Conference Series, E3S Web Conferences, and AIP Conference Proceedings. Meanwhile, most publications in scientific journals (30 articles) were found in the Biodiversitas journal, which is an Indonesian-based journal indexed in Scopus (Figure 4).

It is interesting to note that most of the publications were found in conference proceedings platforms rather than journals. This may be because conference proceedings offer a faster and more efficient process of disseminating the latest research findings and allow researchers to receive direct feedback from peers or experts in the same field. Another possible factor why researchers choose to publish their research in conference proceedings and domestically indexed journals is funding limitations. The publication cost for conference proceedings is lower compared to traditional academic journals, making it a more attractive option for researchers with limited funding. Indonesia's academic system can also play a major role in why the researchers tend to publish in conferences instead of in traditional scientific journals. The pressure to produce more scientific papers as a requirement for career advancement in Indonesia's academic system has led to a preference for conference proceedings over traditional scientific journals (Fry et al., 2023; Sayekti, 2021). This might be

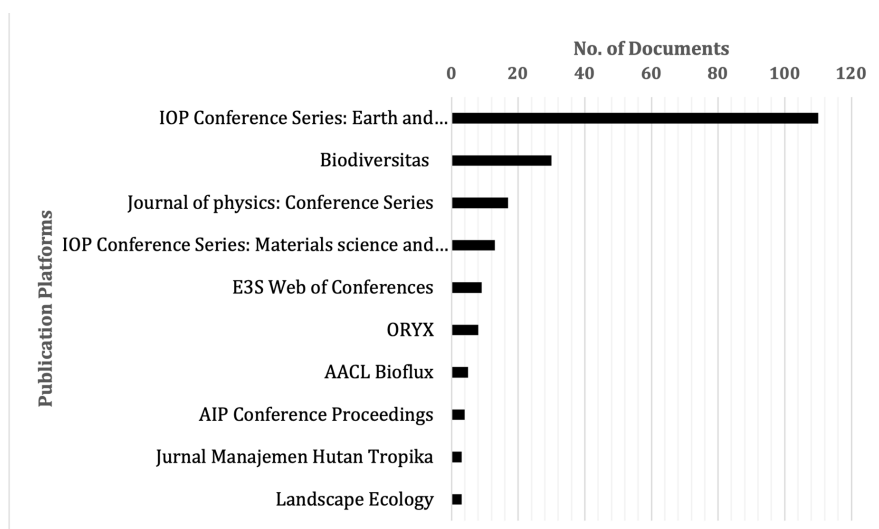


Figure 4. Most relevant publication platforms for scientific articles related to forest conservation in Aceh

partly due to the implementation of a ranking and evaluation system for researchers, which has contributed to an increase in total publications, with a significant portion being conference proceedings (Fry et al., 2023).

A.3. Affiliations

The bibliometric analysis of the affiliations of scientific publications in the field of forest conservation (Figure 5) reveals that Syiah Kuala University is the major contributor, with a total of 322 published articles. Collaboration between various local and foreign institutions also plays an important role, with a total of 137

publications. Other local universities, such as Samudra University, contributed 52 publications, while Bogor Agricultural University and the University of North Sumatra contributed 48 and 41 publications, respectively.

The high number of publications affiliated with foreign institutions in the field of forest conservation (Figure 6) shows a significant level of international collaboration in research related to the scope of forest conservation. This suggests that researchers and institutions in the field of forest conservation recognize the importance of working with colleagues from other countries to enhance the quality of

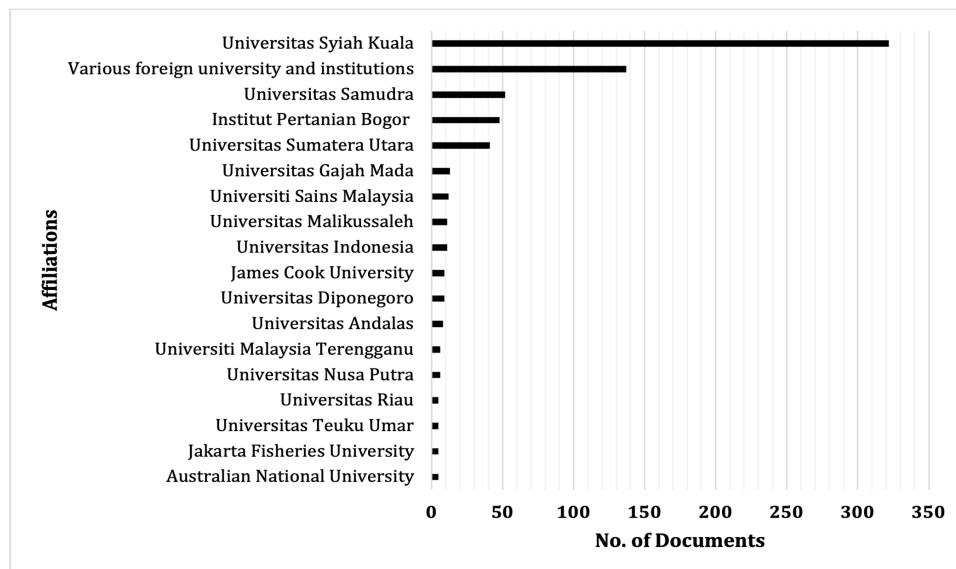


Figure 5. Most relevant affiliations for the scientific publications on forest conservation in Aceh

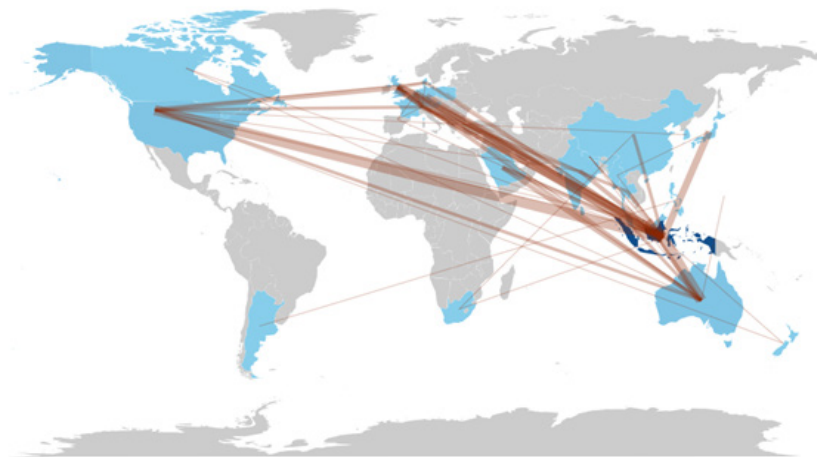


Figure 6. Map of country collaboration network on forest conservation research in Aceh

research and achieve global common goals of forest conservation. International collaboration can combine expertise from various regions, provide access to unique research locations, and enhance potential funding and other resources. The high number of publications affiliated with foreign institutions also emphasizes that research in the field of forest conservation is a global concern and requires cross-border collaboration to address the challenges faced by forests and biodiversity effectively. Since its emergence in the 1990s, the concept of international conservation has evolved and aligned with the increasing significance of collaborative efforts, is reflected in transboundary conservation projects within international treaties such as the Convention on Biological Diversity (Ali, 2010).

B. Knowledge Structure of Scientific Field on Forest Conservation Research in Aceh

B.1. Keywords frequency and topic trends

We analyzed word frequency over time on the keyword plus to find the most used keywords and their accumulation pattern over the years from 1990 to 2023. We excluded a few words related to places (Aceh, province, Indonesia, Sumatra, Nanggroe, Aceh Besar, Malaysia, Greater Sunda, Sunda Isle, Banda Aceh) to focus on the topics of the research.

The keyword frequency numbers represent the number of documents where the keywords are found. This analysis found the most frequently used keywords in forest conservation research in Aceh to be “forestry” (n=59), “conservation” (n=30), “fisheries” (n=27), “ecosystem” (n=24), “biodiversity” (n=22), “sustainable development” (n=16), “tsunamis” (n=16), “disasters” (n=14), “animals” (n=13), and “deforestation” (n=13). The term “biodiversity” has been used in the literature for a longer period than other most frequent terms, dating back to 2002, while the terms “forestry”, “ecosystem”, “tsunami”, and “disasters” started to be used around the year 2004 and 2005. Interestingly, the word although being the second and third most frequently used words, the terms “conservation” and “fisheries” were not found in the scientific literature until 2018.

Moreover, we conducted a trend topic analysis to illustrate the evolution of keyword terms over time and the emergence of new keywords within the topic. As shown in Figure 8, the size of the dots signifies the frequency of the topic words, while the horizontal line represents the temporal span of these keywords. The mapping on keyword trends (Figure 8) shows that forest management, ecosystem services, agriculture, and diversity index were among the most recent topics trending in the field. Additionally, *Pinus merkusii* was found to have been a research

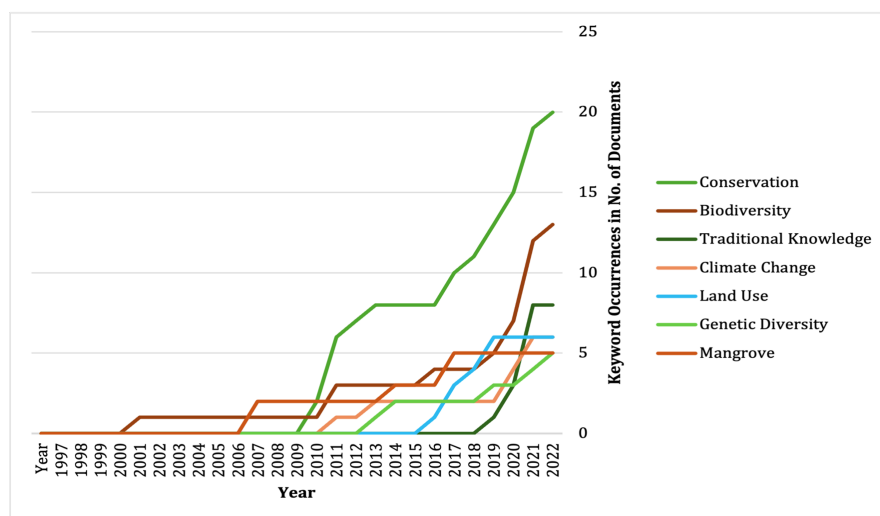


Figure 7. Keywords frequency in scientific publications related to forest conservation in Aceh

keyword cluster is represented by a different color. The brown cluster appears to concentrate on "controlled study" involving "animals" with links to "malaria," alongside mentions of "tree," "agricultural land," and "productivity." The blue cluster primarily focuses on themes of "conservation," "biodiversity," "ecosystems," and "fisheries," with connections to endangered species, the "diversity index," "environmental protection," and "mangrove ecosystems." The purple cluster explores the relationships between "forestry" and "land use," "land cover," "land use change," and "climate change," with mentions of "remote sensing" and "geographical information systems." This cluster also includes discussions on "soils," "water conservation," and "floods." The red cluster interlinks keywords such as "rural areas," "palm oil," "deforestation," "primate," and "Pongo pygmaeus." Lastly, the yellow and green clusters address similar themes, focusing on the "tsunami disaster," "sustainable development," "conservation management," "coastal zone management," and "mangrove forest."

The TreeMap of the 50 most frequently used author's keywords (Figure 10) were also generated to assess the different topics underlying forest conservation in Aceh. The results show consistency with other keyword

analyses performed, wherein the main keywords found to be "conservation", "biodiversity", "traditional knowledge", "climate change", "land use", "mangrove", "deforestation", and 42 other relevant topics as seen in Figure 10.

C. Research Hotspots and Prospects

According to Plenderleith (1998), the concept of conservation first evolved in the 19th century when people started to put value on landscapes and rare plants and animal species. The rise of actions for nature conservation was initiated in the West, which included Europe and North America. This concept was also brought up in Indonesia by the Dutch colonialists around the same period of the 18th to 19th century (Boomgaard, 1999). The result of this study shows that research on forest conservation in Aceh is behind by many decades in response to the evolvement of this topic. The term "conservation" has been used more frequently in recent years (2018-2023), perhaps due to increasing funds directed to reach more untapped regions in Indonesia, including Aceh, and awareness among the scientific community in this province about forest conservation.

The long-standing research interest in *Pinus merkusii* shows the importance of this tree species in Aceh. Researchers are interested in

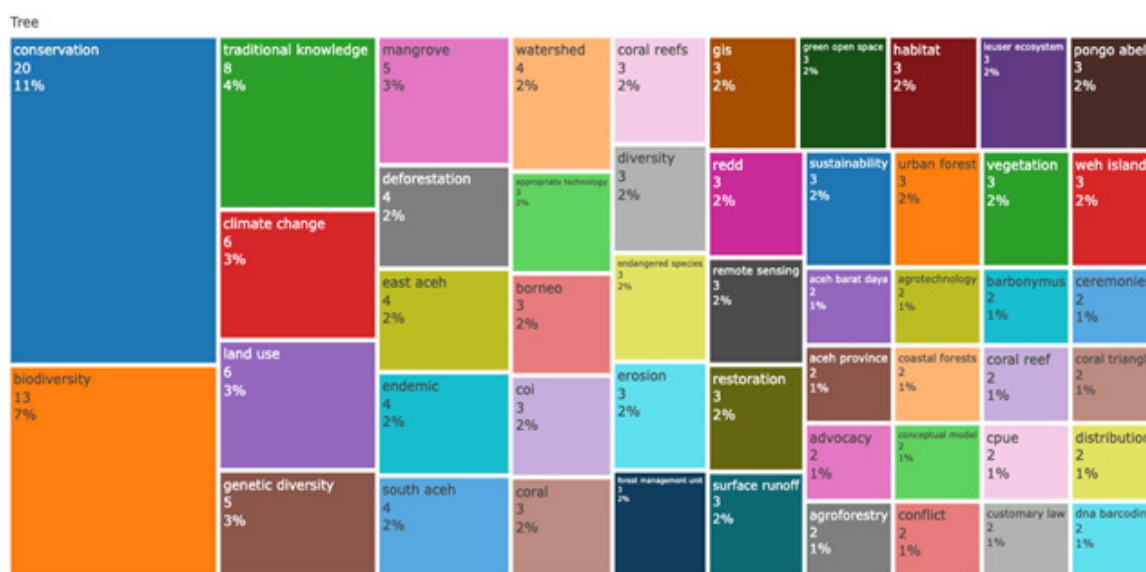


Figure 10. TreeMap of the 50 most frequently used author keywords

understanding the genetic and morphological features of the Sumatran pine (Andini et al., 2022; Siregar & Hattemer, 2004) and how to best manage this species for sustainable forest use (Imanuddin et al., 2020). *Pinus merkusii*, or Sumatran Pine, is an economically and ecologically important species native to Indonesia and other Southeast Asian countries (Imanuddin et al., 2020). This species is native to the region and is commonly used for timber production and sap extraction, among other uses (Andini et al., 2022). It is also widely used in reforestation and rehabilitation efforts due to its adaptability to various environments (Imanuddin et al., 2020). The natural distribution of *P. merkusii* in North Sumatra, Indonesia, is primarily found in clustered populations at elevations between 1000 to 2000 meters above sea level on steep slopes. In Aceh, the largest population of *P. merkusii* is particularly threatened by the expansion of citronella grass plantation for essential oils production, which has led to log of pine trees for firewood (Andini et al., 2022). Conservation efforts, including reforestation and sustainable management, are crucial for the species' survival (Imanuddin et al., 2020).

Recent research on ecosystem services in Aceh Province, Indonesia, has focused on measuring and mainstreaming forest ecosystem services for improved conservation and management. Studies have trained local forest managers and community members in data collection and analysis of key ecosystem services, including forest carbon, tree biodiversity, and forest health (Ar Rasyid et al., 2022; Samek et al., 2022). These efforts aim to support sustainable forest management and inform policy decisions. At the national level, Indonesia is working to mainstream ecosystem services from its remaining forests to achieve Sustainable Development Goals and address challenges like deforestation and climate change (Nugroho et al., 2022).

Keyword co-occurrences cluster on forestry concerning land use and climate change discuss significant forest degradation and conversion

to other land uses, particularly cropland and built-up areas. This transformation has led to decreased carbon stocks, with forests experiencing the highest losses (Achmad et al., 2023). Climate variables, including temperature and humidity, have shown increasing trends linked to land use land cover (LULC) changes. In the Gayo highlands, primary and secondary forests have declined, while mixed dryland agriculture and settlements have expanded (Arico et al., 2023).

The keyword “mangrove” appears in two different clusters. The first one is in the clusters related to tsunami disasters, sustainable development, and coastal zone management. The second cluster is the one closely related to conservation, ecosystem, and fisheries. The documents analyzed show an extensive number of publications focusing on the research of mangroves, as also shown in the keyword analysis results. The research on mangroves has focused on assessing biodiversity, carbon stocks, and ecosystem recovery post-tsunami emphasizing ecological assessments, technological applications, and socio-economic implications. Studies have quantified carbon stock, tree density, and biodiversity in different mangrove areas, which discuss their ecological roles and variations. Remote sensing techniques, such as unmanned aerial vehicles (UAVs) and geographic information systems (GIS) have been employed to analyze mangrove characteristics and spatial distribution, providing critical data for effective management (Azhar et al., 2021). Additionally, investigations into species distribution, litter production, and macrozoobenthic communities have offered insights into the ecological functions and health of mangrove ecosystems. Socio-economic studies have explored the potential of mangrove management to bolster regional economies and the suitability of mangroves for ecotourism. Post-tsunami recovery research has focused on the resilience and adaptation of mangroves to natural disasters, informing restoration efforts (Harefa et al., 2023). The mention of tsunami and coastal zone management is interesting,

as it suggests that the 2004 tsunami disaster in Aceh has had a significant impact on research in this region. The disaster may have prompted researchers to investigate how to better manage coastal zones and forests to mitigate the impact of future disasters. Coastal zone management includes the management of green infrastructure, including coastal vegetation such as beach forests and mangroves. These are the most cost-effective coastal protection which contribute to climate adaptation, ecological conservation, and most importantly, improving coastal resilience against natural disasters, such as Tsunami (Chang & Mori, 2021).

The presence of fisheries in forest conservation studies can be attributed to the interconnectedness of land and water ecosystems. Mangroves, for example, are vital for supporting fisheries. They serve as breeding grounds, nurseries, and habitats for diverse aquatic species, significantly enhancing the socio-economic conditions of coastal communities by providing habitat for economically important species and a source of nutrition (Mhatre, 2024; Nandan et al., 2021; Nugraha et al., 2021). Furthermore, forest management practices can greatly influence water quality, hydrology, and aquatic ecology, thereby impacting fish populations and fisheries (Shah et al., 2022). Conservation efforts often highlight the mutual reliance of forests and fisheries on the functionality of freshwater ecosystems, particularly in biodiversity-rich and economically developing areas (Phang et al., 2019).

Biodiversity being the second most frequently used keyword discusses areas concerning endangered species that focus on threats and conservation efforts for orangutans, elephants, and tigers. Snare trapping poses a significant danger to these species, threatening the last sympatric population of tigers, rhinoceros, elephants, and orangutans in the region. Human-elephant conflicts are a major concern, with community perceptions playing a crucial role in conservation efforts (Berliani

et al., 2016). Studies have mapped elephant distribution in Aceh and North Sumatra that highlight the need for collaborative conservation strategies (Hankinson et al., 2020). Recent research has employed machine learning algorithms to predict the potential ranges of these charismatic mammals, which shows that conservation status and temperature seasonality are critical factors influencing their distribution. Notably, a significant portion of these species' habitats lies outside protected areas, so there is an urgent need for expanded conservation efforts beyond current protected area networks (Rahman et al., 2022).

Despite the comprehensive coverage of research areas, there are still many research niches that remain unexplored in the scope of forest conservation in Aceh. Those include delving deeper into the recently emerging topics such as ecosystem services, forest management and policy, and agriculture relevance with forest conservation. Moreover, we realize that there is a lack of interdisciplinary studies such as the integration of social studies. This can be a big prospect for future studies in forest conservation in the region. Interdisciplinary studies play a crucial role in forest conservation by integrating diverse perspectives and methodologies. They bridge the gap between social and natural sciences, enhancing our understanding of complex socio-ecological systems (Winkel & Jump, 2014). These studies reveal the interconnectedness of history, ecology, and local knowledge in shaping effective conservation policies. By combining ecological and social indicators, researchers can better assess the impacts of land use changes on forest biodiversity and community perceptions (Ravera et al., 2015). Interdisciplinary approaches also help in developing predictive proxy indicators for long-term forest management outcomes (Miller et al., 2017). Moreover, they enable a multidimensional characterization of forest change impacts on human well-being and reconcile explanations from different disciplines (Lele & Kurien, 2011).

IV. CONCLUDING REMARKS

The conservation of forests in Aceh Province is significant for preserving biodiversity, mitigating climate change, and sustaining local livelihoods. The bibliometric analysis conducted in this study discusses the current state of research in forest conservation in Aceh and identifies areas that require more attention. The significant increase in the number of publications since 2007 shows a growing interest and engagement among researchers in this field. There is a peak in publications in 2021 which indicates the continued momentum and commitment to forest conservation in Aceh. The analysis also reveals the influence of the political situation on scientific activities. The decline in publications during the time of Aceh's civil war highlights the adverse impact of conflict on research and scientific publication activities. The post-war period saw a notable shift in the number of publications, suggesting a potential connection between safety, security, and knowledge advancement in forest conservation in Aceh. The analysis of keywords highlights a significant opportunity for future research to adopt a more diverse, interdisciplinary approach to forest conservation, particularly by incorporating social and economic dimensions. While current studies heavily emphasize biological and ecological aspects, integrating socio-economic perspectives would provide a more holistic understanding that addresses both environmental and human factors in forest conservation.

Nonetheless, as the number of publications or citations serves as an approximate estimation of a subject's scientific relevance, the selection of keywords for this research may affect both the quality of the conceptualization from the co-word analysis and the validity of the resulting maps. Furthermore, the inclusion criteria for the publication search limited the analysis to papers written in English, which may introduce biases, especially since the reliance is only on the Scopus database as the sole evaluation tool could limit the result. This sampling strategy

may also overlook articles published in other languages.

ACKNOWLEDGMENTS

The authors thank the anonymous reviewers and editors for their valuable suggestions. We also give special appreciation to Rizka Maulida for her assistance in data acquisition.

REFERENCES

- Achmad, A., Ramli, I., & Nizamuddin, N. (2023). Impact of land use and land cover changes on carbon stock in Aceh Besar District, Aceh, Indonesia. *Journal of Water and Land Development*, 159–166. doi//10.24425/jwld.2023.145346.
- Adnan, B., & Dadi. (2023). Tropical forest conservation efforts as climate change mitigation in Indonesia: A Review. *Interdisciplinary International Journal of Conservation and Culture*, 1(2), 80–89. doi//10.25157/IJCC.V1I2.3633.
- Alam, S., Herawati, T., Hidayat, H., & Wyatt, S. (2019). Forest certification, state regulation and community empowerment: complementarity in seeking a viable solution to forest degradation in Indonesia? *Asia Pacific Journal of Environmental Law*, 22(1), 27–47. doi//10.4337/APJEL.2019.01.02.
- Ali, S. H. (2010). Transboundary Conservation and Peace-building: Lessons from forest projects.
- Andini, R., Melinda, V., Pardede, E., Yanti, L. A., Hmon, K., Moulana, R., & Indrioko, S. (2022). Morphological variation of Aceh pinus (*Pinus merkusii*). *IOP Conference Series: Earth and Environmental Science*, 951(1), 012091. doi//10.1088/1755-1315/951/1/012091.
- Ar Rasyid, U. H., Anhar, A., Subhan, S., Muslih, A. M., Farida, A., Yanti, L. A., Arlita, T., & Umam, A. H. (2022). Soft skill development for ecosystem services measurement to support FMUs and Aceh community forest management. *Repong Damar: Jurnal Pengabdian Kebutanan dan Lingkungan*, 1(1), 79–91. doi//10.23960/rdj.v1i1.5903.
- Arico, Z., Rahmawaty, Delvian, Harahap, H., & Ismail, M. H. (2023). Analysis of land use (2013-2022) in the Gayo highlands, Aceh, Indonesia. *Global Forest Journal*, 1(01). 27–32. doi//10.32734/gfj.v1i01.13252.

- Azhar, R., Rusdi, M., Irham, M., & Fuadi, A. (2021). Spatial distribution of mangrove using a geographic information system in Aceh Besar. *IOP Conference Series: Earth and Environmental Science*, 674(1), 012024. doi//10.1088/1755-1315/674/1/012024.
- Berliani, K., Alikodra, H. S., Burhanuddin, & Kusri, M. D. (2016). Social, economic, cultural and community perception on Sumatran Elephant (*Elephas Maximus Sumatranus*) conflict areas in Aceh Province. *International Journal of Sciences: Basic and Applied Research*, 27, 170–181. <https://api.semanticscholar.org/CorpusID:55517115>
- Bishop, J., Emerton, L., & Thomas, L. (2006). Sustainable financing of protected areas : a global review of challenges and options. IUCN. doi//10.2305/IUCN.CH.2005.PAG.13.en.
- Boomgaard, P. (1999). Oriental nature, its friends and its enemies: Conservation of nature in late-colonial Indonesia, 1889-1949. *Environment and History*, 5(3), 257–292.
- Bullock, R., & Lawler, J. (2015). Community forestry research in Canada: A bibliometric perspective. *Forest Policy and Economics*, 59, 47–55. doi//10.1016/j.forpol.2015.05.009.
- Chang, C.-W., & Mori, N. (2021). Green infrastructure for the reduction of coastal disasters: a review of the protective role of coastal forests against tsunami, storm surge, and wind waves. *Coastal Engineering Journal*, 63(3), 370–385. doi//10.1080/21664250.2021.1929742.
- Cochard, R. (2017). Scaling the costs of natural ecosystem degradation and biodiversity losses in Aceh Province, Sumatra. *Redefining Diversity and Dynamics of Natural Resources Management in Asia*, 1, 231–271. doi//10.1016/B978-0-12-805454-3.00013-X.
- Elsevier. (2023). Scopus Content Coverage Guide. <https://www.elsevier.com/solutions/scopus/how-scopus-works/content>
- Fialka, S. (2022). Assessment of war effects on the publishing activity and scientific interests of Ukrainian scholars. *Knowledge and Performance Management*, 6(1), 27–37. doi//10.21511/kpm.06(1).2022.03.
- Fry, C. V., Lynham, J., & Tran, S. (2023). Ranking researchers: Evidence from Indonesia. *Research Policy*, 52(5), 104753. doi//10.1016/j.respol.2023.104753.
- Gellert, P. K. (2005). The shifting natures of “development”: Growth, crisis, and recovery in Indonesia’s Forests. *World Development*, 33(8), 1345–1364. doi//10.1016/J.WORLDDEV.2005.03.004
- Gumay, D. W., Radinal, Kiswayadi, D., Dirgantara, R., Iriyani, S., & Rusli, I. (2019). Towards Aceh development revitalization based on ecological and biodiversity evidences: the two pieces of terrestrial and marine beyond the facts. *IOP Conference Series: Earth and Environmental Science*, 365(1), 012062. doi//10.1088/1755-1315/365/1/012062.
- Hankinson, E., Nijman, V., & Abdullah. (2020). Asian elephants: 15 years of research and conservation. *Journal of Physics: Conference Series*, 1460(1), 012055. doi//10.1088/1742-6596/1460/1/012055.
- Harefa, M. S., Rohim, N., Pramuja, I., Harahap, P. R., Agustin, S., Siregar, K., & Sitanggang, J. P. (2023). Bio-ecological study on Aceh coast to determine mangrove ecosystem restoration areas suitability. *Depik*, 12(3), 361–372. doi//10.13170/depik.12.3.32211.
- Imanuddin, R., Hidayat, A., Rachmat, H. H., Turjaman, M., Pratiwi, Nurfatriani, F., Indrajaya, Y., & Susilowati, A. (2020). Reforestation and sustainable management of *Pinus merkusii* forest plantation in Indonesia: A Review. *Forests*, 11(12), 1235. doi//10.3390/f1121235.
- IUCN World Heritage. (2020). Tropical Rainforest Heritage of Sumatra - 2020 Conservation Outlook Assessment. <https://worldheritageoutlook.iucn.org/>
- Lassa, J. A. (2010). Strategic group formation for carbon governance in Indonesia after the Indian Ocean tsunami 2004. *International Journal of Disaster Risk Science*, 1(2), 28–39. doi//10.3974/j.issn.2095-0055.2010.02.004.
- Lele, S., & Kurien, A. (2011). Interdisciplinary analysis of the environment: insights from tropical forest research. *Environmental Conservation*, 38(2), 211–233. doi//10.1017/S037689291100018X.
- Linkie, M., Laurance, W., Lynam, A., & Lohmann, L. (2013). From research to responsible advocacy: the Association for Tropical Biology and Conservation finds common ground in Aceh, Indonesia. *Oryx*, 47(3), 324–325. doi//10.1017/S0030605313000732.
- Mhatre, M. A. (2024). Role of mangroves as fishery resource: A systematic review. *Uttar Pradesh Journal of Zoology*, 45(16), 35–41. doi//10.56557/upjoz/2024/v45i164285.

- Miller, D. C., Rana, P., & Benson Wahlén, C. (2017). A crystal ball for forests?: Analyzing the social-ecological impacts of forest conservation and management over the long term. *Environment and Society*, 8(1), 40–62. doi//10.3167/ares.2017.080103.
- Mundzir, I., Mahdi, S., & Hayati, D. (2023). Aceh Sustainable Investment Action Plan 2023.
- Nandan, S. B., Sreelekshmi, S., & harikrishnan, M. (2021). Fishery production potential of the mangroves in India - A Review. *Journal of the Indian Society of Coastal Agricultural Research*, 39(2), 151. doi//10.54894/JISCAR.39.2.2021.110914.
- Nugraha, Y. A., Sulistiono, Susanto, H. A., Simanjuntak, C. P., & Wildan, D. M. (2021). Mangrove ecosystem related to fisheries productivity in the coastal area of Karawang Regency, West Java, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 800(1), 012016. doi//10.1088/1755-1315/800/1/012016.
- Nugroho, H. Y. S. H., Indrajaya, Y., Astana, S., Murniati, Suharti, S., Basuki, T. M., Yuwati, T. W., Putra, P. B., Narendra, B. H., Abdulah, L., Setyawati, T., Subarudi, Krisnawati, H., Purwanto, Saputra, M. H., Lisnawati, Y., Garsetiasih, R., Sawitri, R., Putri, I. A. S. L. P., ... Rahmila, Y. I. (2023). A chronicle of indonesia's forest management: a long step towards environmental sustainability and community welfare. *Land*, 12 (6), 1238. doi//10.3390/land12061238.
- Nugroho, H. Y. S. H., Nurfatriani, F., Indrajaya, Y., Yuwati, T. W., Ekawati, S., Salminah, M., Gunawan, H., Subarudi, S., Sallata, M. K., Allo, M. K., Muin, N., Isnain, W., Putri, I. A. S. L. P., Prayudyaningsih, R., Ansari, F., Siarudin, M., Setiawan, O., & Baral, H. (2022). Mainstreaming ecosystem services from indonesia's remaining forests. *Sustainability*, 14(19), 12124. doi//10.3390/su141912124.
- Phang, S. C., Cooperman, M., Lynch, A. J., Steel, E. A., Elliott, V., Murchie, K. J., Cooke, S. J., Dowd, S., & Cowx, I. G. (2019). Fishing for conservation of freshwater tropical fishes in the Anthropocene. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 29(7), 1039–1051. https://doi.org/10.1002/aqc.3080
- Plenderleith, H. J. (1998). A history of conservation. *Studies in Conservation*, 129–143.
- Prins, H. H. T., & Wind, J. (1993). Research for nature conservation in south-east Asia. *Biological Conservation*, 63(1), 43–46. doi//10.1016/0006-3207(93)90071-8.
- Rahman, D. A., Santosa, Y., Purnamasari, I., & Condro, A. A. (2022). Drivers of three most charismatic mammalian species distribution across a multiple-use tropical forest landscape of Sumatra, Indonesia. *Animals*, 12(19), 2722. doi//10.3390/ani12192722.
- Ravera, F., Tarrasón, D., & Espelta, J. M. (2015). Land use change trajectories, conservation status and social importance of dry forests in Nicaragua. *Environmental Conservation*, 42(1), 1–11. doi//10.1017/S0376892914000186.
- Samek, J. H., Anhar, A., Maimunah, S., & Skole, D. (2022). Measuring forest ecosystem services in Aceh Province for inclusion to local forest resource management plans. *APN Science Bulletin*, 12(1), 90–101. doi//10.30852/sb.2022.1910.
- Sánchez-Azofeifa, G. A., Quesada, M., Rodríguez, J. P., Nassar, J. M., Stoner, K. E., Castillo, A., Garvin, T., Zent, E. L., Calvo-Alvarado, J. C., Kalacska, M. E. R., Fajardo, L., Gamon, J. A., & Cuevas-Reyes, P. (2005). Research priorities for neotropical dry forests 1. *Biotropica*, 37(4), 477–485. doi//10.1046/J.0950-091X.2001.00153.X-I1.
- Sayekti, R. (2021). Applying the concept of rahmatan lil alamin in publication: A transdisciplinary perspective on scientific publication literacy and practices in Indonesian universities. *College & Research Libraries News*, 82(11). doi//10.5860/crln.82.11.513.
- Shah, N. W., Baillie, B. R., Bishop, K., Ferraz, S., Högbom, L., & Nettles, J. (2022). The effects of forest management on water quality. *Forest Ecology and Management*, 522, 120397. doi//10.1016/j.foreco.2022.120397.
- Siregar, I. Z., & Hattemer, H. H. (2004). Patterns of genetic structure and variation of Merkus pine (*Pinus merkusii*) in Indonesia. *Journal of Tropical Forest Science*, 160–172.
- Szomszor, M., Adams, J., Fry, R., Gebert, C., Pendlebury, D. A., Potter, R. W. K., & Rogers, G. (2021). Interpreting bibliometric data. *Frontiers in Research Metrics and Analytics*, 5, 30. doi://10.3389/FRMA.2020.628703.
- Teeguarden, D. (1979). Understanding our forest resources through research. *California Agriculture*.
- Tewari, D. N. (1994). Forestry Research for Sustainable Development. *The Indian Forester*.
- Vincent, J. R., Carson, R. T., DeShazo, J. R., Schwabe, K. A., Ahmad, I., Chong, S. K., Chang, Y. T., & Potts, M. D. (2014). Tropical countries may

- be willing to pay more to protect their forests. *Proceedings of the National Academy of Sciences*, 111(28), 10113–10118. doi://10.1073/pnas.1312246111.
- Wardojo, W., & Masripatin, N. (2002). Trends in Indonesian forest policy. *Policy Trend Report*, 77–87.
- Winkel, G., & Jump, A. (2014). Perspectives on forest conservation: building evidence at the frontier between policy and conservation science. *Biodiversity and Conservation*, 23(14), 3359–3372. doi://10.1007/s10531-014-0824-1.