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Article

Analysis of Deforestation Research Trends in 2015–2024: A Bibliometric Approach on Scopus

Radite Ranggi Ananta[1*], Nur Hayati[2], Hanny Kusuma[3]

[1]Departement of Geography, Universitas Negeri Semarang, Indonesia
[2]Departement of Environmental Science, Universitas Negeri Semarang, Indonesia
[3]Departement of Environmental Science, Universitas Negeri Semarang, Indonesia
*correspondence e-mail: raditeananta@gmail.com

Abstract

This study maps the scholarly landscape on deforestation which cover over 20.000 Scopus papers around 2015–2024 using a bibliometric approach to Scopus-indexed publications. We queried TITLE-ABS-KEY with deforest, "forest cover loss," "land-use change," and "forest conversion," limited to research articles and reviews. Descriptive indicators (annual output and citations; most productive journals, authors, institutions, and countries) were computed with bibliometrix (R), while VOSviewer 1.6.19 generated keyword co-occurrence, co-authorship, and co-citation networks. A geographic subset focusing on Indonesia, particularly East Kalimantan and the Nusantara Capital City (IKN), was examined to connect global patterns with a salient national case. Results show a clear increase in publication volume across the decade and a stable thematic structure organized around four clusters: (1) drivers of forest loss (oil-palm expansion, fires, peat degradation), (2) ecological and climatic impacts (biodiversity loss, carbon emissions), (3) governance (moratoria, law enforcement, supply-chain commitments), and (4) methods (remote sensing, spatial modeling). Overlay analyses indicate rising salience after 2020 of restoration, ecosystem-service valuation, and IKN as an emerging topic. The IKN case underscores trade-offs among development, habitat integrity (e.g., orangutan and proboscis monkey), carbon stocks, and local livelihoods. We identify research gaps in environmental economics, notably the valuation of ecosystem services, incorporation of the social cost of carbon, and rigorous policy evaluation, and highlight the need for credible enforcement, secure tenure, evidence-based spatial planning, and integrated MRV systems. The study contributes a transparent, replicable map of the field to inform research prioritization and policy design; limitations relate to database coverage and keyword standardization.*

Keywords: *deforestation; bibliometric analysis; VOSviewer; Scopus; environmental economics; Nusantara Capital City (IKN)*

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1. Introduction

Forests play a pivotal role in maintaining ecological balance and sustaining biodiversity on Earth (Myrtsidis, 2022). Internationally, a forest is commonly defined as an area with a minimum tree canopy cover of 10% of its total extent that serves as habitat for diverse species and as a reservoir of carbon dioxide (Chazdon et al., 2016). The importance of forests is widely recognized by international organizations, including the United Nations, as a vital component of climate-change mitigation and biodiversity conservation efforts (Anandita et al., 2024). According to FAO (2020), forests contribute to carbon storage, climate regulation, and the provision of sustainable natural resources. They are also often referred to as the "lungs of the world" due to their capacity to absorb CO_2 and generate oxygen (Smith, 2021).

Yet, the current state of the world's forests is increasingly alarming. Recent data indicate that global deforestation continues to rise, with about 10 million hectares of forest lost annually (Global Forest Watch, 2022), driven by human activities such as agriculture, illegal logging, and urbanization (Ritchie et al., 2023). These losses are concentrated primarily in tropical rainforests (Demolin-Leite, 2025). High deforestation rates in tropical forests result in substantial biodiversity loss (Móstiga et al., 2024), soil degradation (Bas et al., 2024),

disruption of the hydrological cycle leading to soil drought (Hallaj et al., 2024), and increased greenhouse gas emissions (Mendoza-Ponce et al., 2021), thereby contributing to climate change through the release of stored carbon into the atmosphere (Tiwari et al., 2021).

Deforestation is therefore among the most pressing environmental challenges globally. FAO (2020) reports that approximately 10 million hectares of forest are lost each year, especially in tropical regions such as the Amazon, Central Africa, and Southeast Asia. At the global scale, deforestation is largely driven by the conversion of forests to agriculture, settlements, or industrial infrastructure (Goers et al., 2011). In the tropics, agricultural extensification has been identified as a principal driver (Jayathilake et al., 2020). Rapidly developing economies also exhibit increased forest conversion to meet global demand for commodities such as palm oil, soy, and livestock products (Curtis et al., 2018). Beyond agricultural expansion, both legal and illegal logging further contribute to forest loss (Kumar et al., 2022).

These processes are reinforced by consumer demand in global markets and by population growth pressures (Binsaeed et al., 2024). Rising populations reduce green cover as more land is required for agriculture and housing (Ceddia et al., 2015). Consequently, rapid urbanization directly drives deforestation for residential and infrastructure development, and indirectly through the displacement of agricultural land (Ma et al., 2024).

The economic ramifications of deforestation are likewise substantial. While short-term gains may accrue from timber extraction and agricultural expansion, the long-term losses from diminished ecosystem services are far greater (Balboni et al., 2023). For example, forest loss can reduce access to clean water and increase the costs of disaster mitigation, in turn affecting agricultural productivity (Abood, 2015). Persistent reliance on deforestation thus risks entrenching poverty and worsening socio-economic conditions.

Indonesia is among the countries facing serious deforestation challenges. Forests cover roughly 44% of the nation's land area; beyond their natural resources, these landscapes support many Indigenous communities whose livelihoods depend on ecosystem integrity (Abood, 2015). Indonesian forests are frequently described as one of the world's "lungs," contributing oxygen essential to life (Shafitri et al., 2018). Forests are critical to economic, social, cultural, and environmental well-being (Widodo & Sidik, 2020). In Indonesia, population growth, forest fires, agricultural expansion, farming practices, drought, timber extraction, and insufficient government attention have all been identified as contributing factors to deforestation (Saragih et al., 2025). The resulting degradation undermines forest functions and drives species loss, with cascading effects including intensified global warming and increased drought risk (Novalia, 2020).

Although government legislation on forest protection sought to reduce deforestation by up to 75% during 2019–2020 (KLHK, 2021), deforestation has persisted at significant rates, particularly in Kalimantan (Wahyuni & Suranto, 2021), driven by illegal practices and conversion for oil-palm plantations. These trends threaten ecosystem integrity and the welfare of communities dependent on forest resources (Naufal, 2021), underscoring the ongoing challenges for sustainable forest management. In Indonesia, the legal definition of forest encompasses areas designated as forest estates, namely production forest, protection forest, and conservation areas. This highlighting the need to understand the environmental and economic consequences of deforestation within this policy context.

Multiple initiatives have been undertaken to curb forest conversion, notably the UN-backed Reducing Emissions from Deforestation and Forest Degradation (REDD+). While REDD+ provides financial incentives for forest conservation (Skutsch & Turnhout, 2020), its effectiveness depends on robust implementation and attention to underlying socio-economic drivers (Hethcoat et al., 2022). Weak law enforcement, unclear land tenure, and global economic pressures remain major barriers to halting deforestation (Angelsen et al., 2018). Addressing this crisis therefore requires stronger international collaboration and a holistic approach engaging government, the private sector, and civil society. Close cooperation between the state and local communities is especially critical to effectively tackle deforestation worldwide.

2. Methodology

This study undertakes a bibliometric analysis of publications on deforestation over the period 2015–2024 using the Scopus database. Bibliometric analysis is a quantitative approach used to examine how knowledge evolves across research domains by analyzing related publications (Marvi & Foroudi, 2023). The units of analysis comprise research articles and review articles. Network visualizations were generated with VOSviewer (version 1.6.19). The bibliometric results were used to identify thematic trends and research gaps, including the Indonesia/IKN theme, which were subsequently enriched through targeted reading of key publications.

The search was conducted in September 2024 in Scopus using the TITLE-ABS-KEY field and restricting the publication years to 2015–2024. The search terms combined the core keyword deforest* with common equivalents—"forest cover loss," "land-use change," "forest conversion"—as well as geographic markers for the Indonesia subset.

The research proceeded in three main stages: (i) specifying retrieval and screening criteria to identify relevant records from Scopus (data collection phase); (ii) transferring the records into VOSviewer to perform bibliometric mapping covering publications, authors, countries, journals/institutions, and subject areas (visualization phase); and (iii) analyzing the mapped data to identify the principal topics in deforestation research emerging in Indonesia (analysis phase).

The study drew on bibliographic information from Scopus-indexed articles published between 2015 and 2024, totaling 20,000 articles. The sampling technique was total sampling. Variables extracted included article title, authors, abstract, keywords, publication year, and source title (journal). Data were retrieved from Scopus using Mendeley Desktop with a single English keyword query, namely "deforestation." The search results were exported from Scopus in CSV format and synchronized with Mendeley Desktop. Topic-trend maps were produced in VOSviewer 1.6.19 from the CSV files. Mapping employed keyword co-occurrence as the unit of analysis, yielding both network and density visualizations of deforestation-related keywords.

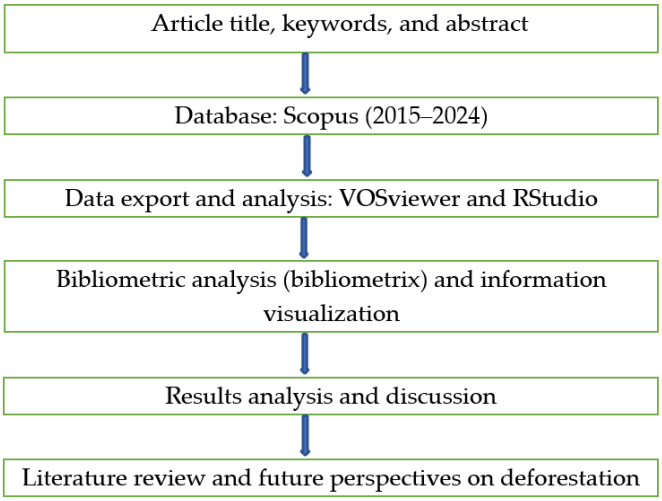

Figure 1. Workflow of the Research

3. Result and Discussion

3.1 Deforestation in Indonesia

Deforestation in Indonesia is a complex environmental issue with significant implications for both the economy and ecosystems. Overall, Indonesia has experienced high levels of forest loss, particularly on the island of Kalimantan, one of the most biodiverse regions in the world. Deforestation in Indonesia is often intertwined with political and economic interests, with rates influenced by government policies and development needs. Historically, deforestation has fluctuated markedly, especially since the 1990s, when national forest cover declined from 63% in 1990 to 49% in 2020. During 1997–2000, deforestation accelerated to 3.8 million hectares per year, driven by forest conversion to agriculture and oil-palm plantations. This surge coincided with a sharp deterioration in environmental quality and underscores the urgency of stronger measures to safeguard natural resources.

Data and trends indicate that deforestation in 2019–2020 was reportedly reduced by up to 75%, with net deforestation at 115.46 thousand hectares. Despite this decline, challenges persist, particularly with the end of the palm-oil moratorium and the potential for increased conversion associated with the Job Creation Law. According to the Ministry of Environment and Forestry (KLHK), 2021–2022 net deforestation reached 104 thousand hectares, down from the previous year's 115.46 thousand hectares. These figures reflect ongoing land-use change, including the conversion of primary forest to oil-palm plantations and industrial zones. Collectively, these trends highlight Indonesia's continuing struggle to maintain forest cover.

In this study, VOSviewer was used to visualize data on 20.000 Scopus articles on forest-cover change, enabling the identification of spatial and temporal patterns of deforestation in East Kalimantan. The maps reveal linkages among topics such as "deforestation", "biodiversity", "land-use change", "forest fires", and "carbon emissions", all of which have pronounced implications for the region's environmental economics. This spatial analysis helps pinpoint the areas most affected by deforestation and provides actionable insights for the Government of Indonesia, particularly East Kalimantan Province and the authority of the Nusantara Capital City (IKN), to design targeted policies that mitigate environmental and local economic impacts.

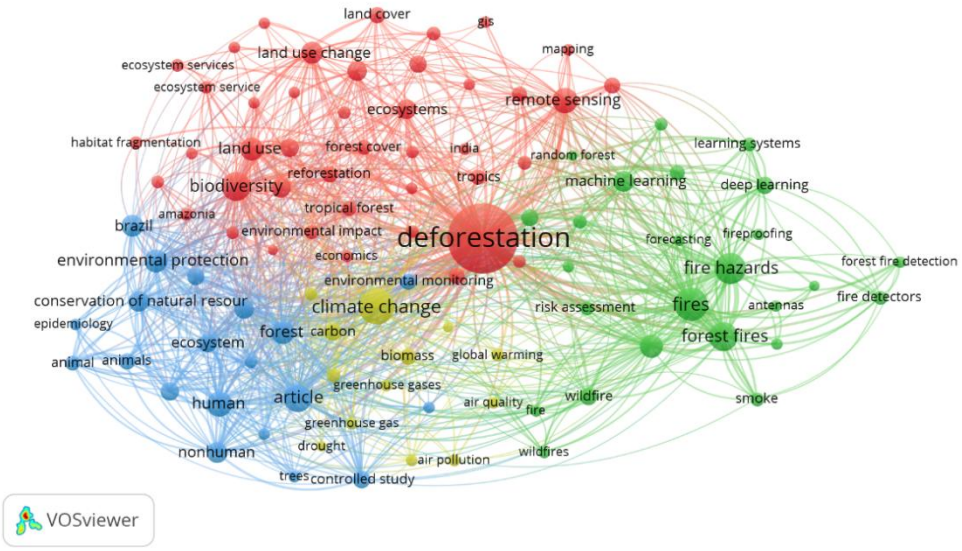

Figure 2. Visualization of Keyword Search Results with VOSViewer

The VOSviewer visualizations also clarify correlations between deforestation and environmental factors with economic repercussions. Forest loss reduces carbon stocks and increases greenhouse-gas emissions, accelerating climate change and elevating the risk of environmental disasters such as floods and landslides. Worsening environmental conditions can raise economic costs, including budget allocations for disaster mitigation and public-health responses to air pollution. Deforestation further drives habitat fragmentation, threatening species survival, lowering land productivity, and disrupting ecosystem balance, ultimately harming economic sectors dependent on natural resources. Identifying these spatial patterns provides a concrete basis for mitigation strategies to reduce further damage and avert long-term impacts, especially in areas prioritized for national development.

Research on deforestation in Indonesia remains relatively limited, as suggested by VOSviewer overlays showing lower-intensity colors for several relevant countries, including Indonesia. This pattern reflects modest public and policy attention to deforestation's substantial environmental and economic consequences, particularly in regions such as East Kalimantan. Deforestation in this area is closely linked to large-scale projects like the IKN, which require extensive land clearing and can degrade forest ecosystems. Several prior studies indicate that large-scale development frequently overlooks long-term environmental sustainability, ultimately disadvantaging local communities.

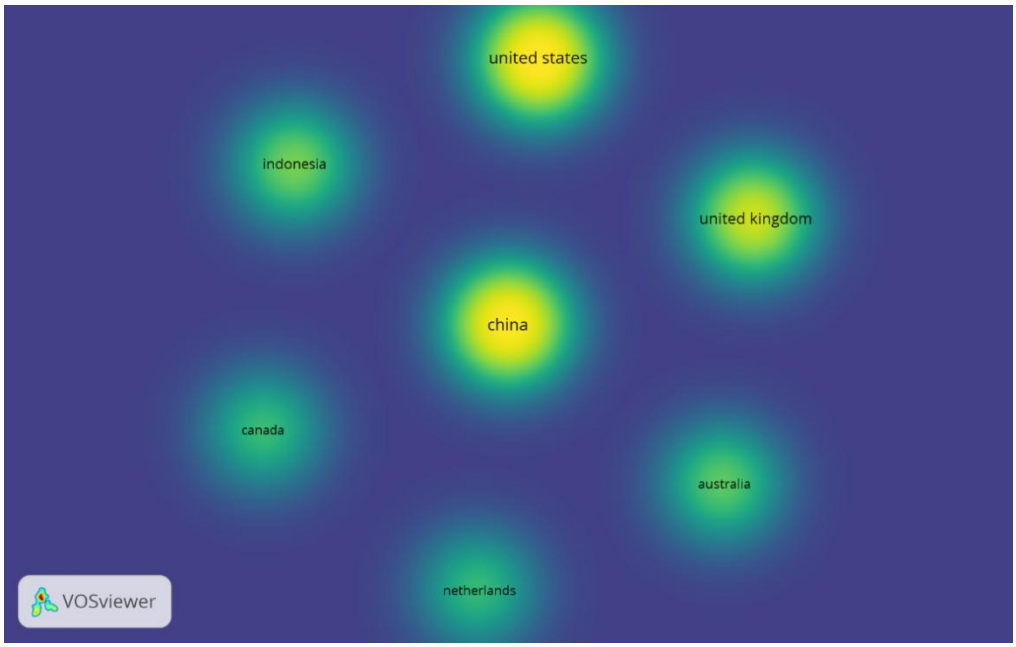

Figure 3. Density Visualization based on country of origin

The VOSviewer maps further indicate that countries with brighter color intensity, such as China, the United States, and the United Kingdom. They demonstrate higher levels of attention to deforestation, as evidenced by more abundant research and publications. By contrast, Indonesia's relatively low volume of deforestation research constrains the evidence base for effective policy design. With limited research output, the public may underestimate the urgency of deforestation, normalizing forest clearing as part of development. This lack of awareness also hampers the implementation of environmentally friendly policies that could minimize negative impacts. Accordingly, Indonesia needs to strengthen research capacity and expand international collaboration to address deforestation, as implied by its comparatively modest position in the VOSviewer maps.

3.2 Drivers and Impacts

One of the most recent threats to Indonesia's forests is the rapid expansion of oil-palm plantations (Xin et al., 2022). Indonesia currently ranks at the top in terms of plantation expansion and planting rates and is the world's leading palm-oil producer. Major production centers are concentrated in five provinces, namely Riau, North Sumatra, Central Kalimantan, South Sumatra, and Jambi. Converting forest land to oil-palm estates is largely driven by rising market demand, which in turn accelerates forest-to-plantation conversion. This expansion reduces local biodiversity and, in many cases, proceeds illegally, including within protected and conservation forests.

Oil-palm expansion entails substantial shifts in land allocation that directly transform landscapes. Emerging problems include the undermining of forests' ecological functions—biodiversity refugia and protection of endangered species (Jayathilake et al., 2022). Loss of forest cover also affects communities in multiple dimensions, for example by increasing the risk of forest fires that trigger cascading disasters such as floods, drought, and the loss of local livelihoods.

Illegal logging refers to timber harvesting carried out without authorization from the relevant authorities and in violation of statutory regulations, for instance, timber theft in state or private forests, or licensed operations that exceed permitted quotas. It is estimated that nearly 50% of timber extraction in natural forests involves illegal logging (Ravindran et al., 2021). Indonesia's tropical rainforests remain a prime target. Contributing factors include economic pressures, educational gaps, and low public awareness.

Forest fires destroy millions of hectares each year. Deforestation from fires often exceeds that from agricultural conversion and illegal logging (Naval et al., 2025). The losses are also greater, including the erosion of genetic resources and direct threats to human life and well-being (health impacts, property damage, and fatalities). Fires result from uncontrolled burning. Human activities, both deliberate and negligent, are reported to

account for 99% of incidents, with indicative shares of 34% land conversion, 25% shifting cultivation, 17% agriculture, 14% social grievances, 8% transmigration projects, and 15% natural causes.

Most deforestation is driven by land-use change for plantations, mining, settlements, infrastructure, and agriculture (Perlin & Leguizamón, 2024). Shrinking forest area threatens myriad species and contributes to carbon emissions that exacerbate global warming. Mining comprises a sequence of activities, including investigation, exploration, feasibility studies, construction, extraction, processing and refining, transportation and sales, and post-mining management. The intensity of mining in Indonesia has risen in part due to increased coal-production quotas set by the Ministry of Energy and Mineral Resources.

Forests that have been degraded gradually lose their ecological functions (Barbanera et al., 2022). "Critical land" is widespread in forest areas damaged by mining; it is also caused by fires and by fragmentation resulting from logging. Mining can create new hazards, such as abandoned coal pits, which have led to environmental damage and even fatalities when water-filled pits are not recognized as such. Deforestation linked to mining also contributes to water pollution in surrounding areas: rivers adjacent to excavation sites are vulnerable to contamination, with consequent disruption to aquatic ecosystems.

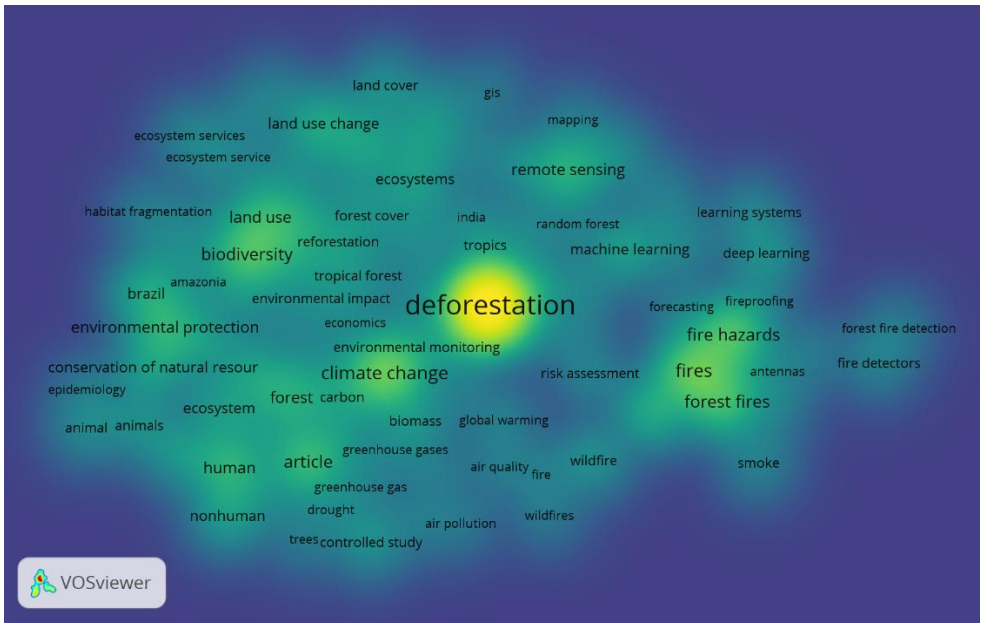

Figure 4. Density Visualization based on the drivers

Climate change is one of the major impacts of deforestation on a global scale. Forests play an important role as natural carbon sinks, helping to maintain the carbon balance in the atmosphere. However, deforestation damages this function because the trees that previously absorbed carbon from the atmosphere have been removed. This leads to the release of carbon into the atmosphere when those trees decompose or are burned, which can contribute to increasing greenhouse gas concentrations and global climate change.

Deforestation turns forests that once acted as carbon sinks into significant sources of carbon emissions. This carbon release contributes to higher concentrations of greenhouse gases in the atmosphere, which in turn affects global climate change and global warming. Carbon emissions from deforestation can disrupt the balance between carbon stored in forests and carbon present in the atmosphere, potentially accelerating the effects of global warming. Therefore, efforts to reduce deforestation and enhance forest conservation are essential for mitigating climate change and global warming.

Biodiversity loss as an impact of deforestation is a significant event in ecology. Forests are home to many species, and deforestation threatens their existence. One important consequence of habitat loss is the disappearance of species that live in the affected area. Deforestation disrupts ecosystem integrity and affects the complex interactions among organisms living within it. Loss of natural forest habitat due to deforestation is one of the greatest threats to biodiversity. Habitat loss disrupts food webs and ecological interactions that are crucial for ecosystem balance. These impacts include losses from biological and ecological perspectives

because declines in species populations can disrupt food-chain balance, reduce ecosystems' ability to withstand external pressures, and potentially damage ecosystem services that benefit humans.

The loss of natural resources due to deforestation refers to the disappearance of elements that are vital for ecosystems and for human and other forms of life. These resources include timber, fertile soils, abundant clean water, and a well-functioning carbon sequestration cycle. When natural resources essential to life are lost, living beings find it difficult to sustain their livelihoods. Therefore, the loss of natural resources due to deforestation harms not only the environment but also threatens the economic and social resilience of communities that depend on those resources.

3.3 IKN Case Study

The relocation of Indonesia's National Capital (IKN) from Jakarta to East Kalimantan, officially announced in August 2019, has raised serious concerns about environmental impacts, particularly deforestation (Yasminnajla et al., 2023). During the period 2018 to 2021, deforestation in the IKN area reached 18 thousand hectares, comprising 14.01 thousand hectares of production forest, 3.14 thousand hectares of Other Use Areas (APL) (Adinugroho et al., 2022), with the remainder in the Grand Forest Park (Tahura), Protected Forest, and other zones. A 2023 report by Forest Watch Indonesia (FWI) shows that deforestation has continued, with an additional 1,663 hectares between 2022 and mid-2023. Forest loss in East Kalimantan has serious impacts on ecosystems, including the loss of habitat for endemic species such as the orangutan and bekantan, as well as threats to essential forest ecological functions (Syaban & Appiah-Opoku, 2024).

Kalimantan is one of the world's biodiversity hotspots, with more than 700 vertebrate species, most of which are endemic and some of which are endangered. Moreover, the report indicates that 30% of Kalimantan's area has experienced deforestation over the last 50 years, especially in biodiversity-rich primary forests. As forests disappear, many types of flora, fauna, and ecosystem functions that have long supported local livelihoods and helped balance the climate will also be lost. The construction of the National Capital (IKN) is projected to expand the development area by up to 30 km by 2045.

The forests of Kalimantan, covering 8.26 million hectares in East Kalimantan, including protected and conservation areas, are increasingly threatened by the expansion of ports and toll roads to support IKN development. Balikpapan Bay, which hosts an important mangrove ecosystem, is also threatened by infrastructure development that may affect bekantan habitat and the critical balance of marine and terrestrial ecosystems in the area. Ongoing deforestation can also affect Indigenous and local communities who depend heavily on forests for food, traditional medicine, and cultural and social values. The impacts are acutely felt by local residents who have long lived alongside forests and utilized natural resources sustainably. Without appropriate mitigation, land-use change and forest fragmentation resulting from the IKN project could lead to the local extinction of orangutans within the next 50 years.

As a solution, the "forest city" concept has been proposed to create a sustainable city through the planting of vegetation and green open spaces that function as habitat for local fauna and help reduce air and noise pollution. Therefore, it is important to implement policies that protect the remaining forest areas and ensure the sustainability of ecosystems in East Kalimantan in the face of rapid development.

Deforestation in Indonesia, particularly in relation to the development of the National Capital (IKN) in East Kalimantan, has a major impact on environmental economics and ecosystems. Although the IKN project aims to create a modern and sustainable city, there are serious concerns about potential damage to forests that serve as the lungs of the world. This development not only affects local ecosystems but also threatens the livelihoods of communities that depend on local natural resources.

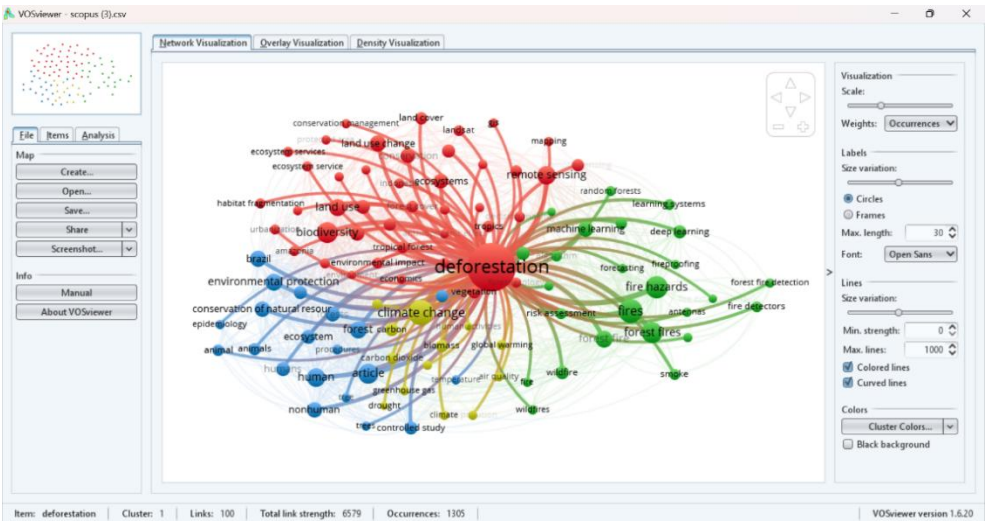

Figure 5. Linkages between IKN and Deforestation

The construction of IKN is expected to trigger large-scale deforestation. Between 2018 and 2021, around 18 thousand hectares of forest were lost, with 14 thousand hectares originating from production forest. Recent reports reveal that only 43% of the IKN area remains forested, while the other 57% has been converted to non-forest areas. This process results in the loss of habitat for flora and fauna and reduces the forest's functions as a carbon sink and regulator of the microclimate. Deforestation in the IKN area poses a serious threat to environmental economics. Forest loss means the loss of vital resources for local communities, such as fishers and small farmers who rely on forest ecosystems. They lose access to land used for hunting, farming, and fishing. Infrastructure such as dams and ports built in this project has changed land use, triggering conflicts between project needs and the interests of local communities.

The forests of Kalimantan, known as the lungs of the world, are at risk of damage from massive deforestation. The loss of forest cover eliminates its vital roles in water conservation, maintaining soil stability, and regulating the microclimate. As a result, the risks of natural disasters such as erosion, pollution, flooding, and landslides increase as protective vegetation declines. Forest rehabilitation efforts in Indonesia remain very limited. Data from the Ministry of Environment and Forestry (KLHK) show that only about 900 hectares of forest can be restored each year, with low success rates. It would take nearly a century to return forests to their original condition, indicating that the negative effects of deforestation will persist long after the development project is completed.

In addition, deforestation in IKN undermines Indonesia's efforts to reduce carbon emissions globally. Increased deforestation makes it more difficult for the country to meet international commitments to curb emissions, which could result in sanctions or trade restrictions, harming Indonesia's economy in the long term. The development of IKN tends to benefit a handful of parties, such as large corporations holding land concessions in the area. Around 51% of land in IKN is controlled by various companies, while local communities are often marginalized. This imbalance creates social and economic injustice, with most of the benefits of development not being felt by the communities most affected.

4. Conclusion

Deforestation in Indonesia is a multidimensional and acute environmental challenge driven by the expansion of plantations, mining, illegal logging, and large-scale infrastructure development. In East Kalimantan, pressures intensify in connection with the Nusantara Capital City (IKN) project, accelerating habitat fragmentation, land-use conversion, and the release of stored carbon. The ecological consequences are wide-ranging: the loss of habitat for endemic and threatened species, reduced landscape connectivity, disruption of hydrological cycles with higher risks of flooding, drought, and erosion, soil degradation, and diminished carbon stocks and sequestration capacity. These changes erode ecosystem resilience and weaken the flow of ecosystem services that underpin human well-being. The social and economic repercussions are equally significant. Indigenous and local livelihoods are compromised; public expenditures for disaster mitigation and environmental health rise; and tenure disputes and distributional conflicts become more likely. Over the

medium to long term, ecosystem degradation increases external costs and opportunity costs, undermines regional competitiveness, and jeopardizes the foundations of sustainable development.

Bibliometric evidence covering 2015–2024 indicates that the scholarly conversation is dominated by themes related to land-use drivers, ecological and climatic impacts, governance, and monitoring methods, while notable gaps remain in environmental economics, particularly ecosystem-service valuation, the social cost of carbon, and rigorous evaluations of policy effectiveness. Emerging issues such as IKN underscore the need for quantitative, interdisciplinary, and cross-scalar analyses that link remote sensing with socioeconomic data and translate scientific findings into implementable policy. Ultimately, reducing deforestation depends on the combined force of credible law enforcement, secure land tenure, evidence-based spatial planning, and economic incentives aligned with conservation outcomes; without this alignment, short-term growth will continue to deplete the very natural capital on which long-term prosperity depends.

Recommendations

Policy responses should prioritize robust enforcement and legal certainty over land tenure, integration of conservation into IKN planning through clearly delineated no-go zones and a strict mitigation hierarchy, and jurisdictional approaches coupled with NDPE (No Deforestation, No Peat, No Exploitation) commitments across supply chains. Restoration must target ecologically critical systems, such as peatlands, mangroves, and degraded watersheds, while post-mining reclamation is guaranteed by financial assurance and compliance audits. Fire management should emphasize prevention, early warning, and accountability for open burning, alongside viable, fire-free livelihood alternatives for smallholders. Economic instruments, including payment for ecosystem services, green credit, land-use taxation, and the systematic incorporation of ecosystem-service values and the social cost of carbon into public cost–benefit analyses are essential to realign incentives.

On the research and implementation fronts, future work should broaden evidence bases beyond Scopus to include Web of Science and Google Scholar; ensure transparency and reproducibility through full reporting of search strings, VOSviewer parameters, and node/edge data; and advance analytical depth via co-citation clustering, author–country collaboration mapping, and thematic evolution analysis. Building a unified Monitoring, Reporting, Verification system that integrates satellite imagery, carbon inventories, and community-based reporting will improve decision relevance, especially in East Kalimantan hotspots. Finally, translating findings into policy briefs, priority-area maps, dashboards, and accessible public communication while fostering stakeholder forums that include government, academia, the private sector, and communities, will increase uptake. Incorporating environmental economics, bibliometric methods, and remote sensing into curricula and professional training will help institutionalize the capabilities needed to align Indonesia's development goals with durable forest conservation.

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