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BIBLIOMETRIC AND NARRATIVE LITERATURE REVIEW ON CARBON PRICING FOR FORESTRY AND LAND USE

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ABSTRACT

Economic activities not only enhance human well being, but also create environmental degradation. One significant form of this degradation is climate change caused by greenhouse gas (GHG) emissions. In Indonesia, the highest GHG emissions come from energy sector and Forest and Other Land Use (FOLU) sector. Emissions in FOLU sector caused by deforestation, forest fire, oil palm productions, etc. This study aims to analyzed the research trends about implementation of carbon pricing especially in FOLU sector. Bibliometric analysis was conducted by employing 929 research data from the Scopus database published from 2003 to 2023. The research was using VOS viewer to visualised research topics and cluster analysis. Due to limited access to the full texts of the relevant articles, this study employed a narrative literature review approach, as a systematic literature review could not be conducted under these constraints. This study found that many articles explain about how land-use change resulting from oil palm plantation expansion is a major driver of peatland alteration and a significant source of carbon emissions in the land-use change sector in Indonesia. It was found from the bibliographic study that recent studies have increasingly focused on topics such as blue carbon, carbon neutrality, carbon tax, etc. In line with this, methodological approaches like computable general equilibrium models, and scenario simulation are being used more frequently in current research on carbon pricing. The most prominent and widely discussed research topics include land use change, deforestation, climate change, etc.

Keywords: bibliometric, carbon pricing, low carbon development, sustainable development, forestry and land use.
JEL Classification: Q54, Q58, Q15, O44.

INTRODUCTION

Although industrialized nations have historically been the primary contributors to global CO_2 emissions, several developing countries have also emerged as major emitters. The reduction of greenhouse gas emissions and the implementation of sustainable policies are critical responsibilities that must be undertaken by all nations (Lu et al., 2022).

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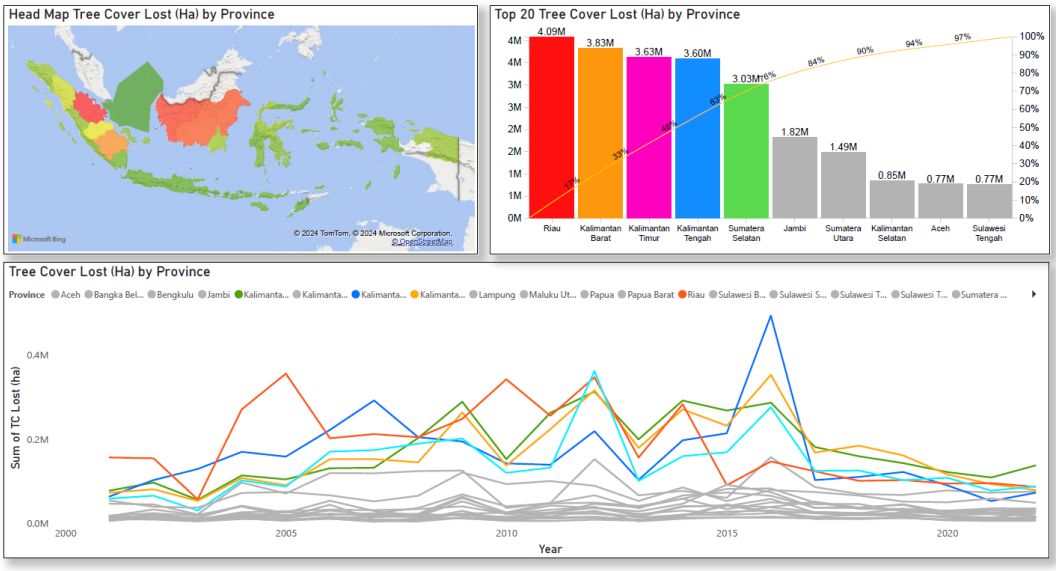
In Indonesia, the forestry and land use secto r (FOLU), along with forest fires, is the second-largest contributor to greenhouse gas (GHG) emissions after the energy sector. Although there was a temporary decline in emissions or an increase in carbon absorption between 2001 and 2003, Indonesia's forest, ideally expected to act as a carbon sink, have instead become a significant source of emissions. This is largely due to deforestation, land-use change and recurring forest fires (BPS, 2022).

Deforestation is characterized by, among other things, a decrease in the area of tree cover or vegetation in a region. According to data from the World Resources Institute (WRI), below is an overview of the country's tree cover loss in Indonesia from 2001 to 2022.



Source: Data retrieved from WRI (World Resources Institute, 2024), https://www.wri.org/

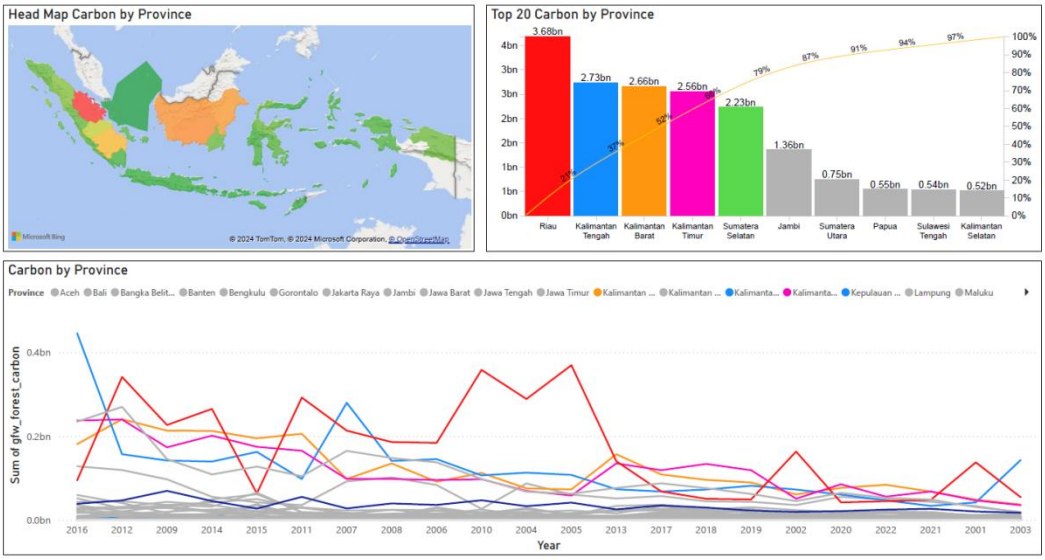
Figure 1. Tree Cover Loss (Ha) per Province Indonesia

Figure 1 shows the condition of tree cover loss in each province of Indonesia. The image reveals that several areas in Sumatra and Kalimantan experienced high tree cover loss, surpassing other regions in Indonesia. The provinces with the highest tree cover loss from 2001 to 2022 are Riau, West Kalimantan, East Kalimantan, Central Kalimantan, and South Sumatra.

The increasing rate of tree cover loss in Indonesia has been accompanied by a rise in carbon emissions from the forestry sector. This trend is reflected in data on forest carbon gross emissions, which represent the total carbon released from forested areas, excluding any carbon sequestration occurring within these ecosystems. A primary driver of these emissions is deforestation, often undertaken to convert forest land into agricultural areas, residential zones, or infrastructure projects. Such activities result in the release of carbon previously stored in tree biomass and soil into the atmosphere. In addition, forest carbon emissions may also arise from wildfires, whether caused intentionally or by natural factors.

Figure 2 presents the forest carbon gross emissions in Indonesia between 2001 and 2022. Although emissions have generally declined across all provinces since 2017, they continue to occur to this day. The highest emissions were recorded in Riau, followed by Central

Kalimantan, West Kalimantan, East Kalimantan, and South Sumatra. Collectively, these five provinces account for 79% of the total forest carbon gross emissions among the top ten highest-emitting provinces in the country.



Source: Data retrieved from WRI (World Resources Institute, 2024), https://www.wri.org/

Figure 2. Carbon Emission (MgCO2e/year) from Forest per Province Indonesia

(Jia, G., et.al, 2019), emphasizes that changes in land use are a major contributor to global greenhouse gas emissions. Conversions in land cover, including deforestation for farming and urban expansion, play a significant role in increasing CO_2 and other greenhouse gases. Around 23% of total anthropogenic emissions in the world, come from the Land Use, Land-Use Change and Forestry (LULUCF) sector.

Carbon emissions from land-use change sector are indeed crucial to discuss, especially since Indonesia has a significant reserve of tropical forests. Today, the Indonesian government has ratified climate change mitigation policies through carbon pricing and the NDC (Nationally Determined Contribution). Research on carbon pricing policies has expanded as the mechanism has recognized as a key economic tool for tackling environmental challenges. In fact, economic and environmental interests often conflict with each other, which is why government intervention is necessary to align these interests. This is especially important to achieve sustainable development.

In this study, bibliometric analysis will be used to identify research trends and map publications related to the topic of Carbon Pricing Analysis in the Land-Use Change Sector and Low Carbon Development Planning. This objective is addressed by analyzing several specific aspects, including trend in annual publication growth, evolution and positioning of research on this topic, current or emerging topics being studied, and the most prominent or widely discussed themes. It also identifies recommended research themes for future exploration, countries that most productive or have the highest impact in this field, the structure of international research collaboration, institutions that contribute the most publications, the most prolific authors, and journals or publishers that frequently publish work on this topic.

After the bibliometric analysis, a narrative literature review was conducted. This approach was chosen not only due to limited access to full-text journal articles, but also to enable a more flexible synthesis of key insights from diverse sources.

RESEARCH METHOD

This study adopts a mixed-method literature review, combining bibliometric analysis and narrative synthesis. The bibliometric component was based on metadata from Scopus to identify research trends, influential publications, and thematic clusters, while the narrative review draws on selected full-text articles that were accessible to the researcher and thematically relevant to the research topic. Unlike systematic reviews, which involve a structured and replicable method for searching and selecting literature, this review is based on a purposeful selection of articles that were accessible in full-text format to the author. The included articles were collected from various sources, including Scopus-indexed journals, institutional repositories, and open-access platforms. Although the selection process was not systematic, the articles were chosen based on their relevance to the research topic.

The data search was conducted in the Scopus database on March 25, 2024. Scopus is one of the largest abstract and citation databases of peer-reviewed literature, widely used for bibliometric analysis, literature reviews, and research performance evaluations. It indexes a broad range of journals across scientific, technical, medical, and social sciences disciplines (Burnham, 2006).

The search was conducted using keywords aligned with standard terms found in a thesaurus (see Table 1).

Table 1. Keyword selection based on the research topic and the use of truncation symbols

carbon pricing	land use	land use change	low carbon development
“carbon pric*”	“land use”	forest	“low carbon development”
“carbon tax*”		deforestation	
“carbon trad*”		"forest conversion"	
“carbon emission*”		"forest depletion"	
“carbon offsetting”		"forest-land conversion"	

The search was performed within the Title, Abstract, or Keywords (Title-Abs-Key) to broaden the results, allowing keywords to be found in any of these three fields. The search covered publications published between 2003 and 2023, including all document types and source types. The subject areas were limited to *Environmental Science*, *Social Sciences*, *Economics, Econometrics and Finance*, and *Multidisciplinary*. The language of publication was restricted to English only. The search steps are presented in Table 2.

Table 2. Data Search Procedure

Search Steps	Search Strings	Total Records
Initial search in the Title, Abstract, or Keyword.	(TITLE-ABS-KEY ("carbon emission*" OR "carbon pric*" OR "carbon tax*" OR "carbon trad*" OR "carbon offsetting" OR "low carbon development") AND TITLE-ABS-KEY ("land use") AND TITLE-ABS-KEY (forest OR deforestation OR "forest conversion" OR "forest depletion" OR "forest-land conversion"))	1,304 publications
Filter 2 Limitation to a specific year range	2003-2023	1,219 publications
Filter 3 Subject area	Include: Environmental science; Social sciences; Economics, Econometrics and Finance; Multidisciplinary Exclude: Biochemistry, Genetics and Molecular Biology, Medicine, Chemistry, Pharmacology, Toxicology and Pharmaceutics, Agriculture and biological science, Chemical engineering, Physics and astronomy, Immunology and microbiology, Engineering, Computer science, Energy, Earth and planetary sciences, Mathematics, Economics, econometrics and finance, Decision sciences, Business, management and accounting, Arts and Humanities	968 publications
Filter 3 Language	English	929 publications

After conducting data retrieval and filtering, the metadata of 929 publications was exported as a CSV file, then analyzed and visualized using VOSviewer software.

RESULTS AND DISCUSSION

Trend of Annual Publication Growth

The number of publications related to the topic has gradually increased over the years (Figure 3). The development of publications over time can serve as a useful tool to assess the growth of a particular research topic (Wijaya, A., Setiawan, N. A., & Shapiai, 2023). Increase in the number of publications may indicate a growing research interest in the topic. As illustrated in Figure 3, publications on this topic have shown consistent growth annually.

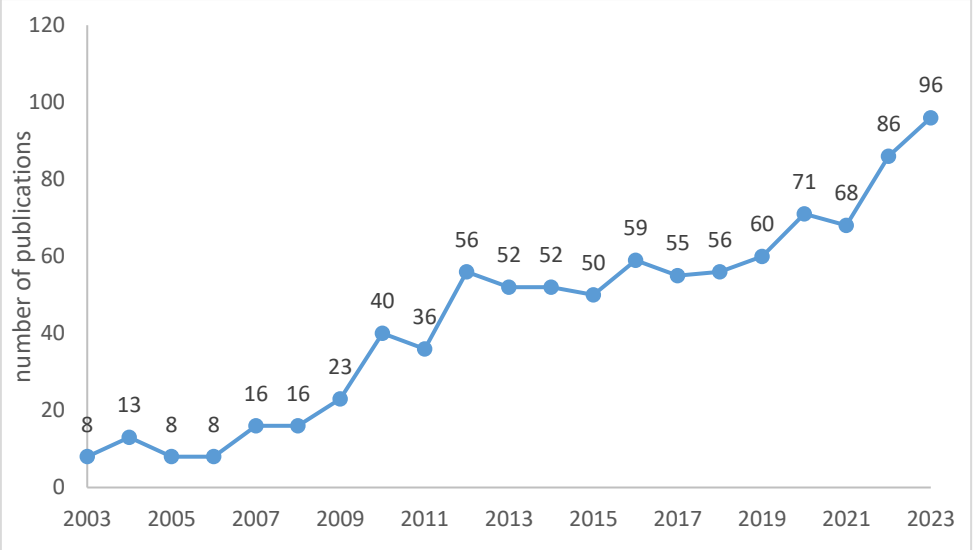


Figure 3. Trend of annual publication growth

Research Trend and Positioning on the Topic

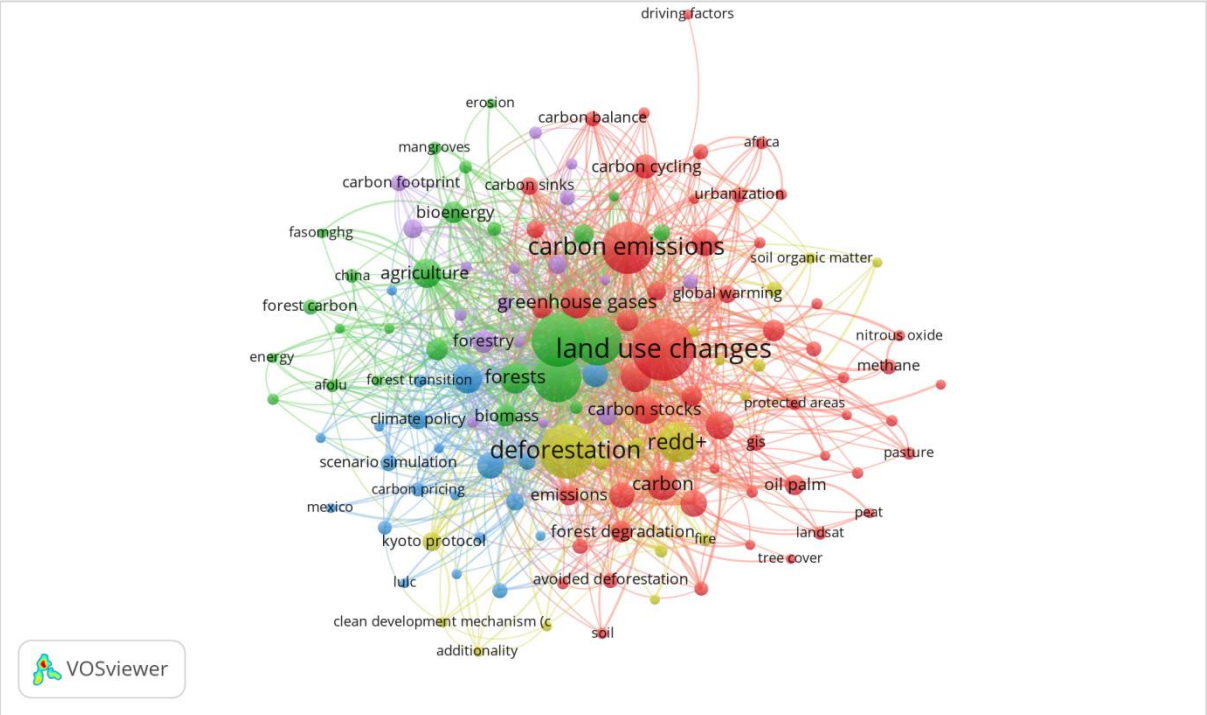


Figure 4. Visualization of the keyword network

Research topic trends were analyzed using keyword co-occurrence in VOSviewer. The analysis used author-defined keywords (keywords assigned by the authors themselves), as they better reflect the content of the publications than machine-generated ones. From 2,386 keywords, 162 keywords met the minimum occurrence threshold of four. Furthermore, these 162 keywords were cleaned (e.g., standardizing spelling such as converting singular forms to

plural), resulting in 137 unique keywords. The keyword co-occurrence network visualization is shown in Figure 4, where the 137 keywords are grouped into five clusters (see Table 3). Keywords grouped within the same color (cluster) may indicate a thematic connection within a specific research area. Frequently used keywords are represented by larger labels. The connecting lines (links) indicate co-occurrence relationships, and the thickness of the lines reflects the strength of these co-occurrences.

Table 3. Distribution of keywords within each cluster

Cluster	Keywords
1 (red)	Africa, agroforestry, albedo, amazon, avoided deforestation, carbon, carbon balance, carbon cycling, carbon dioxide, carbon dioxide emissions, carbon emissions, carbon fluxes, carbon neutrality, carbon pools, carbon sinks, carbon stocks, carbon storage, cropland expansion, driving factors, emissions, forest degradation, forest management, gis, global warming, greenhouse gas emissions, greenhouse gases, indonesia, land cover change, land use changes, landsat, meta-analysis, methane, modeling, nitrous oxide, oil palm, oil palm plantation, opportunity costs, pasture, peat, protected areas, radiative forcing, redd, remote sensing, secondary forest, shifting cultivation, soil, soil carbon, tree cover, tropical deforestation, tropical forests, tropical peatland, urban forest, urbanization, wetlands, wood products
2 (green)	Adaptation, afolu, agriculture, bioenergy, biomass, blue carbon, bookkeeping model, carbon budget, carbon leakage, carbon sequestration, carbon tax, china, climate change, energy, erosion, fasomghg, forest carbon, forests, land management, land use, landscape, mangroves, mitigation, negative emissions, soil organic carbon
3 (blue)	Afforestation, brazilian amazon, carbon pricing, climate change mitigation, climate policy, computable general equilibrium, degradation, ecosystem services, forest conservation, forest transition, lulc, lulucf, mexico, nature-based solutions, paris agreement, reducing emissions from deforestation and forest degradation, reforestation, scenario simulation, sustainable development, unfccc, wildfire
4 (yellow)	aboveground biomass, additionality, biodiversity conservation, biofuels, clean development mechanism (cdm), climate, deforestation, fire, governance, invest model, kyoto protocol, land cover, modis, monitoring, palm oil, redd+, soil organic matter, spatial analysis
5 (purple)	agricultural expansion, biodiversity, brazil, carbon accounting, carbon footprint, carbon trading, conservation, forest biomass, forestry, indirect land use change, life cycle analysis, peatlands, random forest, southeast asia, sugarcane, sustainability, uncertainty

From cluster 1 (red), we can have a main topic about carbon management and land use change in tropical regions. Related issues such as deforestation and forest degradation, agroforestry and sustainable land use, peatlands and wetlands, urbanization and land cover change, carbon accounting and monitoring, greenhouse gas emissions, policy and mechanisms, etc.

From cluster 2 (green) we can have a main topic about carbon mitigation strategies in the AFOLU sector under climate change. The key issues, such as carbon sequestration and storage, climate change mitigation policies, negative emissions and bioenergy, etc.

From cluster 3 (blue) we can have a main topic about climate change mitigation through forest based and land use policies. The key issues are about forest-based mitigation strategies, land use and carbon accounting, carbon pricing and economic modelling, etc.

Cluster 4 (yellow) may have a main topic about monitoring and governance of land based climate mitigation in the context of deforestation and sustainable development. Issues that are related about land based climate mitigation mechanisms, deforestation, fire, and palm oil expansion, monitoring and spatial analysis tools, biodiversity and ecosystem conservation, governance and policy implementation and so on.

Cluster 5 (purple) can have a main topic about sustainable land use and carbon accounting in agriculture and forestry. The key issues are about agricultural expansion and land use change in Brazil or South East Asia, carbon metrics and environmental impact, forestry and conservation, carbon markets and policy instruments (carbon trading), modeling and uncertainty, and so on.

The Most Current/Updated Topics Reviewed

The most recent topics can be identified through the overlay visualization of keyword co-occurrence analysis, as shown in Figure 5 below. This visualization traces the historical progression of research. Darker circles represent studies conducted further in the past, while lighter, yellowish hues indicate more recent investigations. The results reveal that current research focuses on topics such as blue carbon, carbon neutrality, carbon tax, climate change mitigation, wildfires, urbanization, and oil palm plantations. Additionally, methods like random forest, computable general equilibrium, and scenario simulation have become increasingly prevalent in recent studies on carbon pricing.

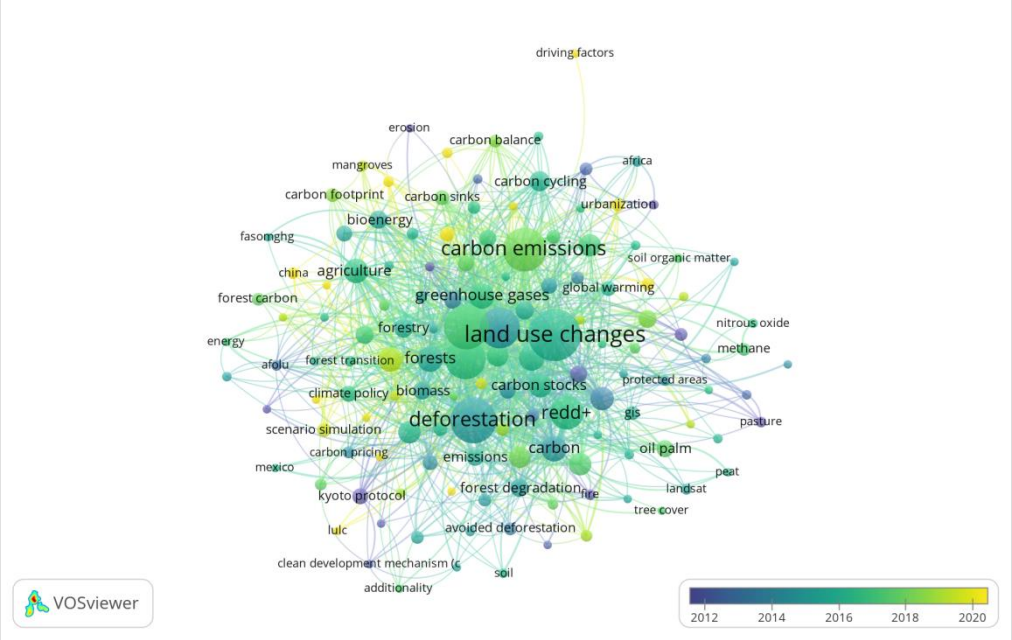


Figure 5. Overlay Visualization of Keywords

Prominent, Numerous, and Diverse Topics Discussed

The most prominent or frequently conducted types of research can be observed from the keyword co-occurrence through the density visualization shown in Figure 6. In the density item visualization, each item is represented by its label, like the network and overlay visualizations. Each point in the density visualization is coloured to indicate the item's density at that location. By default, colours range from blue to green to yellow to red. The higher the number of items around a point and the greater the weight of surrounding items, the closer the colour of the point shifts toward yellow and red. Conversely, the fewer the items and the lower their weight around a point, the closer the colour moves toward blue.

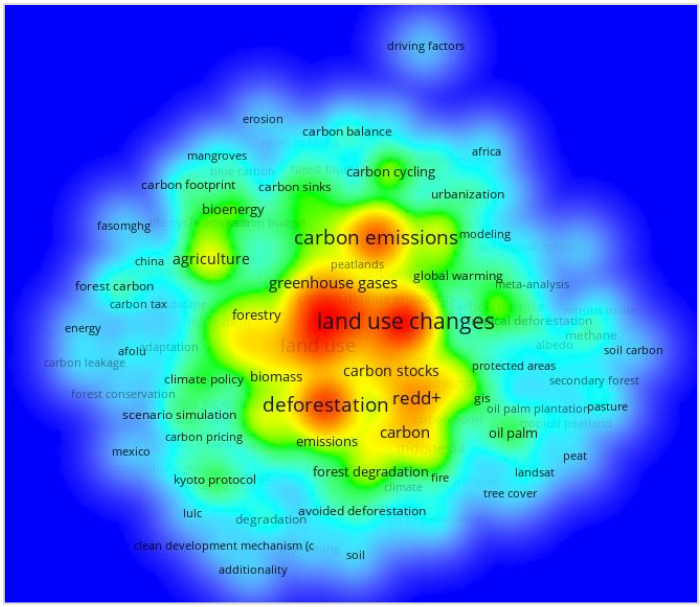


Figure 6. Keyword Density Visualization

Based on the analysis of keyword weight occurrence, total link strength, and weight link (the connections between keywords indicating their co-usage), the most prominent and frequently discussed research topics are related to:

- Land Use Changes: covering land conversion from agriculture to urban areas, deforestation, and habitat transformation.
- Deforestation: examining forest loss and its effects on biodiversity, water cycles, and the environment.
- Climate Change: understanding causes, impacts, and strategies for mitigation and adaptation.
- Carbon Emissions: investigating sources such as fossil fuel burning and their role in global warming.
- Land Use: studying optimal land utilization for agriculture, urban development, and conservation.
- Carbon Sequestration: exploring methods to capture and store atmospheric carbon, including reforestation and land management.
- REDD+: a global initiative to reduce emissions from deforestation and forest degradation, while promoting sustainable forest conservation and land use.

Research Theme Recommendations Related to the Topic

Topics that have been less explored and could serve as research recommendations can be identified from the density visualization (Figure 6) by examining the keywords located on the outermost edges (aqua-colored). Keywords in this aqua zone have low weight occurrence and total link strength, meaning they are less connected to the dominant keywords (yellow-red). Therefore, under-researched topics may relate to keywords such as driving factors, clean development mechanism (CDM), soil carbon, soil organic matter, tropical peatland, shifting cultivation, LULC (land use and land cover), adaptation, carbon leakage, and FASOM-GHG (Forest and Agricultural Sector Optimization Model with Greenhouse Gases).

Country's Productivity

Table 4 and Figure 7 present the top ten countries with the highest number of publications related to the topic of Carbon Pricing Analysis in the Land-Use Change Sector and Low-Carbon Development Planning. This information on national productivity can help identify which countries are most promising as references for further study and potential collaboration. The most dominant contributor to publications on this topic is the United States, with 321 documents (cited 575 times). China ranks second with 151 documents (cited 10,965 times), followed by the United Kingdom in third place with 122 documents (cited 15,076 times).

Table 4. Top 10 Countries with the Highest Number of Research Publications

Rank	Country	Number of articles	Number of citations
1	United states	321	30617
2	China	151	10965
3	United kingdom	122	15076
4	Germany	99	5908
5	Brazil	84	4776
6	Indonesia	79	4011
7	Australia	77	8705
8	Netherlands	60	3016
9	Canada	48	7222
10	India	36	804

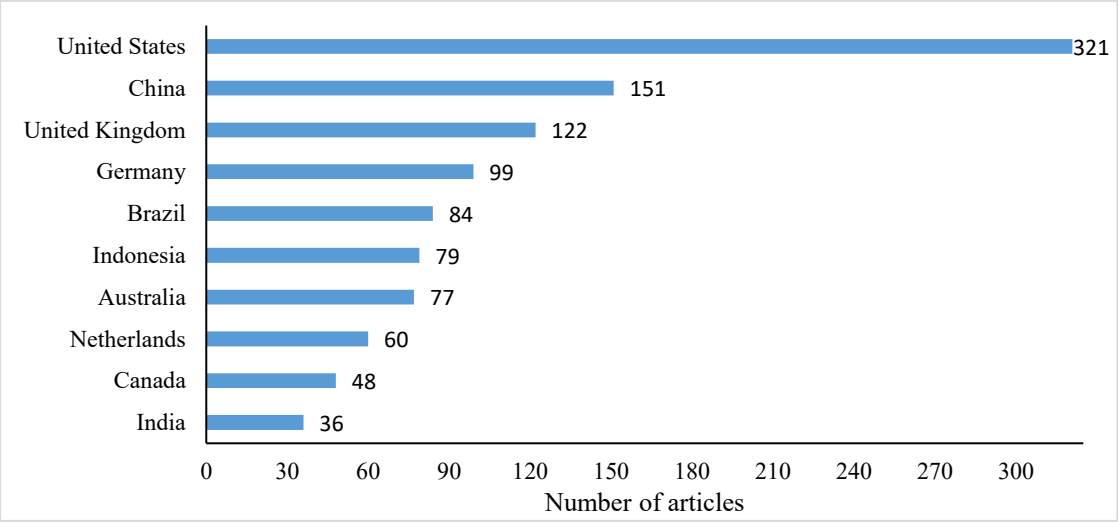


Figure 7. Countries with the Highest Number of Research Publications

International Research Collaboration

Figure 8 shows the network of country collaborations that have produced publications related to the topic of Carbon Pricing Analysis in the Land-Use Change Sector and Low Carbon Development Planning. Out of 98 countries, 34 have published at least 10 documents. Among these 34 countries, those with the highest levels of collaboration (as indicated by link weights) are Germany, the United Kingdom, and the United States, each with a link weight of 32.

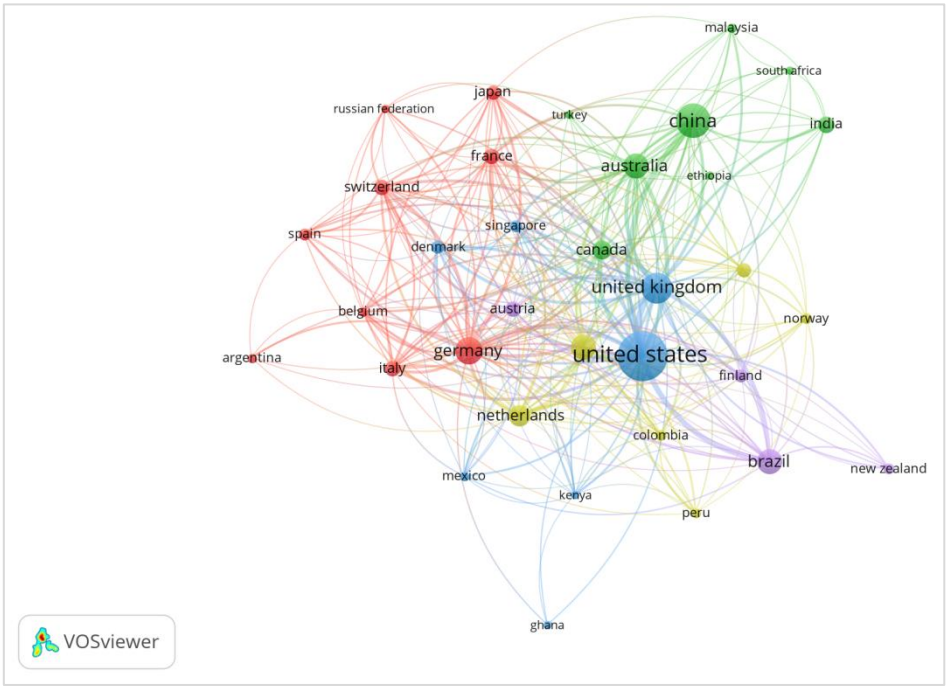


Figure 8. Visualization of International Research Collaboration Network

Research Productivity by Institution

Table 5 and Figure 9 present the top ten institutions with the highest number of publications related to the topic of Carbon Pricing Analysis in the Land-Use Change Sector and Low-Carbon Development Planning. This institutional information can help identify potential collaborators for future research. The institution with the highest number of publications on this topic is the Chinese Academy of Sciences from China, with 47 documents.

Table 5. Top 10 Institutions with the Highest Number of Research Publications

Rank	Institution	Number of articles
1	Chinese Academy of Sciences	47
2	Wageningen University & Research	40
3	Woods Hole Research Center	34
4	USDA Forest Service	31
5	Center for International Forestry Research	30
6	University of Maryland	24
7	Instituto Nacional de Pesquisas Espaciais	21
8	Oregon State University	21
9	Humboldt-Universität zu Berlin	20
10	Universidade de São Paulo	20

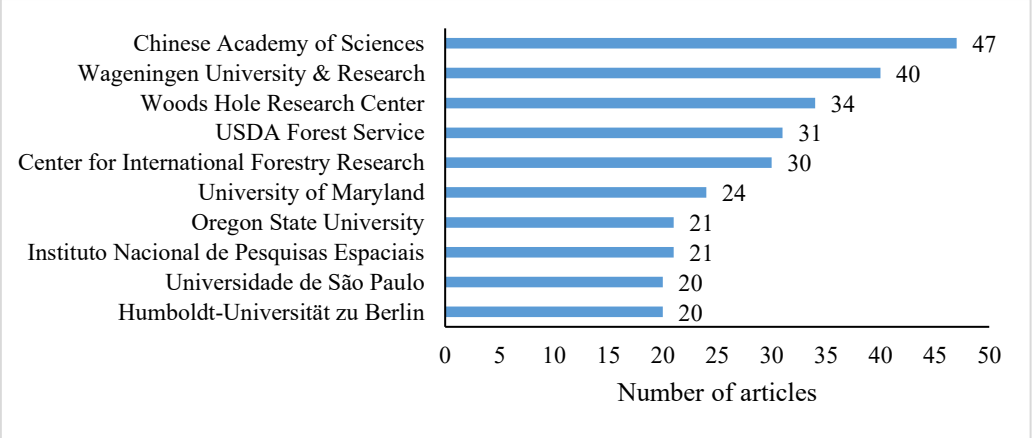


Figure 9. Institutions with the Highest Number of Research Publications

Research Productivity by Author

Table 6 and Figure 8 present the top ten authors with the highest number of publications related to the topic of Carbon Pricing Analysis in the Land-Use Change Sector and Low-Carbon Development Planning. The most prolific author is Richard A. Houghton, with 16 documents cited 7,790 times. Alexander Popp ranks second with 11 documents (cited 718 times), followed by Linda S. Heath in third place with 10 documents (cited 703 times).

Table 6. Top 10 Authors with the Highest Number of Publications on the Topic

Rank	Author	Number of articles	Number of citation
1	Houghton, Richard A.	16	7790
2	Popp, Alexander	11	718
3	Heath, Linda S.	10	703
4	Lotze-Campen, Hermann	10	683
5	Ciais, Philippe	7	6649
6	Dietrich, Jan Philipp	7	547
7	Müller, Daniel	7	201
8	Obersteiner, Michael	6	1243
9	Wise, Marshall	6	1093
10	Koh, Lian Pin	6	858

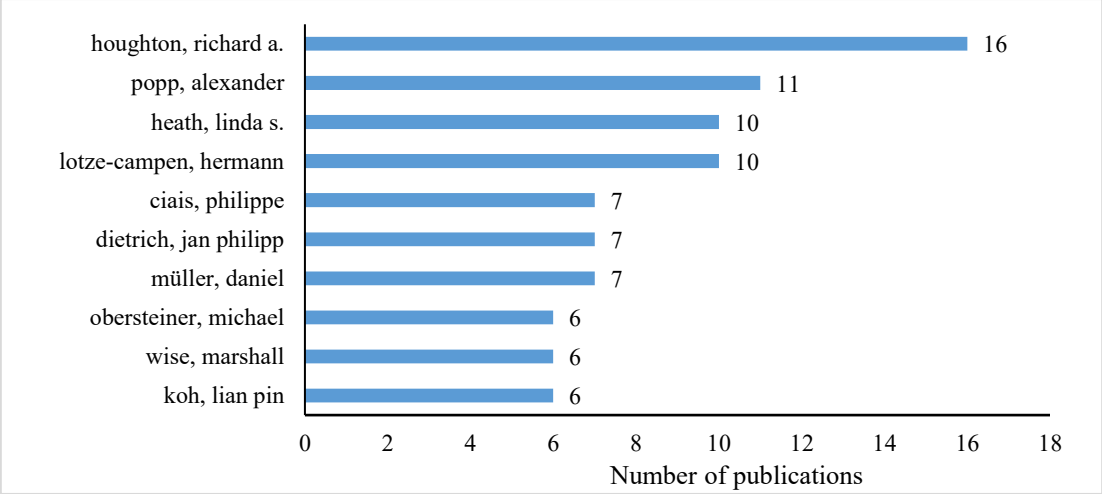


Figure 8. Authors with the Highest Number of Research Publications

Publishers/Journals with the Most Publications on the Topic

Table 7 provides information on the top ten journal sources that have published the most articles and received the highest citations related to the topic of Carbon Pricing Analysis in the Land-Use Change Sector and Low-Carbon Development Planning, along with details on their subject scope and quartile ranking. This information can be useful for selecting target journals for publication or for reference searches. The journal with the most publications on this topic is Global Change Biology, published by Wiley-Blackwell Publishing Ltd, with 48 documents cited 6,670 times.

Table 7. Top 10 Journal Sources with the Highest Number of Publications

Rank	Journal	Number of Articles	Number of Citation	Publisher	Subject Area	Quartile
1	Global Change Biology	48	6670	Wiley-Blackwell Publishing Ltd	Environmental Science (Ecology, Environmental Chemistry, Environmental Science (miscellaneous), Global and Planetary Change)	Q1 (Ecology)
2	Environmental Research Letters	43	1658	IOP Publishing Ltd.	Energy (Renewable Energy, Sustainability and the Environment), Environmental Science (Environmental Science (miscellaneous)), Medicine (Public Health, Environmental and Occupational Health)	Q1 (Environmental Science (miscellaneous)
3	Science of The Total Environment	42	1405	Elsevier	Environmental Science (Environmental Chemistry, Environmental Engineering, Pollution, Waste Management and Disposal)	Q1 (Environmental chemistry)
4	Forest Ecology and Management	28	1650	Elsevier	Agricultural and Biological Sciences (Forestry), Environmental Science (Management, Monitoring, Policy and Law, Nature and Landscape Conservation)	Q1 (Forestry)
5	Land Use Policy	27	919	Elsevier	Agricultural and Biological Sciences (Forestry), Environmental Science (Management, Monitoring, Policy and Law, Nature and Landscape Conservation), Social Sciences (Geography, Planning and Development)	Q1 (Forestry)
6	Mitigation and Adaptation	22	608	Springer Netherlands	Environmental Science (Ecology, Global and Planetary Change)	Q1 (Ecology)

7	Strategies for Global Change Global Environmental Change	21	1809	Elsevier	Environmental Science (Ecology, Global and Planetary Change, Management, Monitoring, Policy and Law), Social Sciences (Geography, Planning and Development)	Q1 (Ecology)
8	Journal of Environmental Management	21	548	Academic Press Inc.	Environmental Science (Environmental Engineering, Management, Monitoring, Policy and Law, Waste Management and Disposal), Medicine (Medicine (miscellaneous)	Q1 (Environmental Engineering)
9	Sustainability (Switzerland)	20	133	MDPI AG	Computer Science (Computer Networks and Communications Hardware and Architecture), Energy (Energy Engineering and Power Technology, Renewable Energy, Sustainability and the Environment), Environmental Science (Environmental Science (miscellaneous), Management, Monitoring, Policy and Law), Social Sciences (Geography, Planning and Development)	Q1 (Geography, Planning and Development)
10	Carbon Balance and Management	19	699	BioMed Central Ltd.	Earth and Planetary Sciences (Earth and Planetary Sciences (miscellaneous)), Environmental Science (Global and Planetary Change, Management, Monitoring, Policy and Law)	Q1 (Earth and Planetary Sciences (miscellaneous))

Narrative Literature Review

The goals of economic growth and environmental conservation often conflict with each other. Economic development involves activities such as industrial expansion, infrastructure construction, and resource extraction. They are frequently lead to environmental degradation, including deforestation, pollution, and loss of biodiversity. On the other hand, environmental conservation may impose restrictions on economic activities to preserve natural resources and ecosystems. There are trade-off between pursuing rapid economic growth and ensuring long-term environmental sustainability.

Raihan & Tuspekova (2022) finds a positive relationship between economic growth and CO_2 emissions, indicating that higher economic growth leads to higher emissions. In contrast, renewable energy use and forest area are negatively associated with CO_2 emissions, indicating that increased use of renewables and larger forest cover help reduce emissions. The findings suggest that promoting renewable energy and sustainable forest management can effectively lower carbon emissions in Malaysia. Therefore, policies supporting a low-carbon economy, renewable energy adoption, and sustainable forest practices are recommended to achieve environmental sustainability.

In Indonesia, the moratorium on converting natural forests to palm oil plantations negatively impacts Indonesia's economic growth and other macroeconomic indicators. The effects vary by region, with Sumatra facing the largest economic losses and Kalimantan seeing the most benefits. The study suggests that additional policy measures are needed to address the unequal regional impacts of the moratorium (Yusuf et al., 2018).

Land use change and deforestation

Classical economists such as Adam Smith and David Ricardo viewed land, especially fertile land, as an important and limited factor of production. They believed that due to the scarcity of fertile land, agricultural output would experience diminishing returns. Additionally, they recognized the unique services provided by land that are not traded in markets and emphasized its role in the production process. This was challenged by Keynes. He emphasized the role of expectations and uncertainty in investment decisions, thereby broadening the analysis of the role of land and natural resources in economics. Keynes encouraged a more dynamic approach to understanding land's role in the economic context. Agricultural Economics has evolved to recognize land as a crucial and dynamic resource, addressing soil depletion and environmental sustainability. This reflects increased awareness of ecological limits and the need for a holistic, multidisciplinary approach that considers land's economic, social, and environmental importance (Hubacek & Van Den Bergh, 2006).

In a growing economy with an increasing population, land becomes a scarce and valuable resource. This often leads to competition and changes in how land is used. One major result is land use change, where natural areas are converted for agriculture, housing, or industry. This frequently causes deforestation, driven by expanding plantations and development, which impacts natural ecosystems and local communities.

The main drivers of land use change in the United States include economic and population growth, climate change, dietary shifts, and trade policies. Dietary shifts, particularly the rise in meat consumption, can drive agricultural land expansion to meet food demand.

Additionally, trade policies can influence land use changes, such as increased agricultural exports that encourage the expansion of farmland (Gurgel et al., 2021).

In Southeast Asia, predictions based on the latest FAO Forest Resource NYDF Assessment 2020 and land-use/carbon stock models indicate that Southeast Asia's natural forest area is expected to decline by about 1.1 million hectares per year (~0.51%) from 2000 to 2030, partly offset by an annual increase of roughly 169,000 hectares in plantation forests. Deforestation in Southeast Asia contributes significantly to global tropical forest carbon emissions, accounting for about 17% of total emissions from tropical deforestation and degradation worldwide (Sasaki et al., 2021).

Brunner et al., (2005) argues for stronger forest law enforcement in Southeast Asia, emphasizing the role of local communities as more reliable and cost-effective actors compared to state agencies. However, enforcement can have negative consequences, including loss of livelihoods, displacement, inequality, and potential human rights violations. Effective forest governance thus requires equitable partnerships between governments and communities.

Verstegen et al., (2019) examined three land use and land cover scenarios (Business-as-Usual, Development, and Conservation) from 2015 to 2030 in Pulang Pisau, Central Kalimantan. The Business-as-Usual scenario showed a decline in habitat quality, especially in protected areas. The Development scenario, which included planned agricultural expansion, resulted in the most significant habitat degradation due to increased anthropogenic pressures. In contrast, the Conservation scenario, focusing on forest restoration, led to substantial improvements in habitat quality. Overall, the study highlights that conservation-oriented approaches offer the greatest benefits for biodiversity compared to Business-as-Usual and Development pathways.

Another land cover change model is for the Berbak area in Jambi Province, Sumatra, predicts a significant decline in forest cover, especially peat swamp forests, by 2040. The highest forest loss (over 60%) is expected in logging concession areas, while protected forest areas show a lower loss of 25% compared to 52% in unprotected areas. Under a business-as-usual scenario, forest cover, which was 185,000 ha in 2010, is projected to decrease by 37% by 2040. Nearly half of the study area's protected forests will see a 25% decline in coverage, with peat swamp forests declining by almost 37%. The largest increases in land cover will be in plantation/regeneration areas (including oil palm) and open land, each growing by about 30,000 ha (Elz et al., 2015).

The primary direct drivers of deforestation and land cover change in Riau Province, Indonesia, are the expansion of oil palm and timber plantations. These activities have been identified as the main causes of forest loss in the region. In addition, legal and illegal logging also significantly contribute to land cover change in Riau (Juniyanti & Situmorang, 2023).

In Indonesia, forests offer vital ecosystem services such as nutrient cycling, habitat for biodiversity, erosion and flood control, and cultural values like recreation and education. To reduce deforestation and promote sustainability, Indonesia enforces policies like logging moratoriums, strengthens law enforcement against illegal logging, restores degraded forests, and supports community-based forest management through programs like Social Forestry. Key strategies include conservation policies, sustainable management, restoration, community involvement, and enhanced monitoring. However, their success depending on effective implementation (Nugroho et al., 2022) and (Calvin et al., 2014).

Indonesia's government action plan for emission reduction in the forestry sector has been ineffective, with emissions increasing by 38% between 2010 and 2014. (Tacconi & Muttaqin, 2019). Several studies highlight the limited effectiveness of forestry and land-use policies in curbing deforestation. Indeed, Wahyuni & Suranto (2021) finds that large-scale deforestation in Indonesia has serious implications for global warming. Between 1985 and 1998, deforestation rates reached 1.6 to 1.8 million hectares annually, rising to 2 million hectares by 2000, making Indonesia the third-largest emitter of greenhouse gases after the United States and China. It concludes that stronger efforts are needed to reduce deforestation and its climate impact. Sari et al., (2023) finds that without forest conservation, natural forests in Kalimantan, Indonesia, will suffer significant losses over the next 30 years. Although conservation efforts reduce forest loss, some natural forests outside protected zones remain vulnerable to conversion. The research highlights the critical need for policies to preserve Indonesia's natural forests. Barber & Canby (2018) finds that illegal logging is one of the main drivers of deforestation and a major challenge to sustainable forest management. It is closely linked to corruption and organized crime within the forestry sector. The study highlights the importance of law enforcement and collaboration among governments, international institutions, and civil society in combating illegal logging and strengthening sustainable forest governance. Furthermore, Suwarno et al., (2018) shows that the forest conversion moratorium policy in Indonesia has not been effective in reducing deforestation and carbon emissions. It recommends combining the moratorium with livelihood support and price incentives for forest and agroforestry products at the farmer level. Local-level policy adjustments are considered essential to enhance both the effectiveness and the social and environmental benefits.

Implementation of agrarian reform and social forestry programs in Indonesia faces significant challenges, including limited understanding of the schemes, inappropriate site allocation, and insufficient attention to community capacity and local governance. The implementation of social forestry also has the potential to undermine emission reduction efforts and forest conservation goals. In Central Kalimantan, lack of capital hinders both forest protection and income generation under the program. The study also identified risks and concerns related to land permit allocation and the government's focus on granting permits without providing adequate resources for implementation (Resosudarmo et al., 2019).

Despite various policy efforts, their outcomes have been insufficient in addressing deforestation, which remains a critical issue in Indonesia. One of the primary contributors to deforestation in Indonesia is the expansion of agricultural activities, which continues to exert pressure on forested areas. Agricultural expansion increases carbon emissions by converting vegetated land into farmland, while forest loss reduces carbon stocks through tree removal. Tian et al., (2021) found that land use changes contributed 26.54 Pg C in emissions (1.15 Pg C per year) from 1992 to 2015, with agricultural expansion as the main source and forest loss reducing carbon storage. Juniyanti et al., (2021) found that agricultural expansion, mainly oil palm plantations, logging, and timber estates, is the primary drivers of land use change in Sumatra and Kalimantan. Underlying causes include institutional challenges like unclear property rights and weak capacity, along with policies such as transmigration. Economic, technological, political, and social factors also play roles. Key actors driving land change include pulp and paper conglomerates linked to political elites, local officials with military

backgrounds, and regional military commanders. They promote timber plantations and coordinate logging activities, significantly altering land use in the regions.

Rustiadi et al., (2023) show that demographic policies and plantation development also have a significant impact on land cover change, rural development transformation, and economic growth in Jambi, Indonesia. The analysis indicates a shift in the typology of rural areas in line with regional dev elopment progress. Data collected at the provincial and village levels reveal positive trends in economic conditions, infrastructure, and land cover in rural areas. However, challenges remain, including increasing economic inequality and ongoing deforestation in the region. The study recommends controlling land use change, diversifying the economy beyond the palm oil sector, and promoting indigenous community-based economic initiatives as strategies to address these challenges. In addition, the study highlights the impact of transmigration programs and plantation expansion on deforestation and rural development dynamics.

Palm Oil and Rubber Expansion: Impacts on Peatlands and Mangrove Ecosystems

Primary forests in Kalimantan are declining due to the expansion of oil palm and rubber plantations, especially in lowland areas near settlements and roads. Without conservation efforts, forest loss could reach up to 50% by 2050. (Sari et al., 2023).

The main factors contributing to greenhouse gas emissions from tropical peatlands in Southeast Asia include excessive logging, deforestation, drainage, land-use change, and fires. These activities disrupt the stability of peatland ecosystems and accelerate the decomposition of organic matter stored in the soil, releasing significant amounts of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) into the atmosphere. Greenhouse gas emissions from peatlands contribute substantially to the global carbon budget and accelerate the pace of climate change. The findings of this study demonstrate that tropical peatlands in Southeast Asia, especially in Indonesia, Malaysia, and Papua New Guinea, store significant amounts of carbon and are impacted by land-use changes and fires, resulting in greenhouse gas emissions. Different land uses, such as oil palm and pulpwood plantations, exert varying effects on carbon emissions (Rieley & Page, 2007).

The expansion of oil palm plantations in Indonesia, Malaysia and Papua New Guinea significantly contributes to CO_2 emissions in the area through forest conversion, peat oxidation, and peat excavation/drainage (Agus et al., 2013). Oil palm plantations also a significant source of deforestation and carbon emissions in West Kalimantan Indonesia (Carlson et al., 2012). The greenhouse gas (GHG) footprint of palm oil production in Indonesia varies significantly across regions, with differences of up to 35-fold. The main factors contributing to the variability of the carbon footprint in palm oil production in Indonesia are emissions from changes in carbon stocks, forest edge degradation, peat burning, peat drainage, and fresh fruit bunch yields (Lam et al., 2019).

Between 1973 and 2005, extensive fires, drainage, and selective logging significantly influenced land cover changes and forest loss in the peat swamp forests of Central Kalimantan, Indonesia. The Mega Rice Project (MRP), initiated in 1995 to convert peatlands into agricultural land, accelerated deforestation and degraded the landscape by causing excessive drainage and making the peatlands highly susceptible to fires. As a result, 72% of peat swamp forests were lost to fires during 1997–2005, mostly replaced by non-woody vegetation. Peatland fires contribute substantially to carbon emissions, with Southeast Asian peatlands

releasing an estimated 0.6 gigatons of CO_2 annually due to peat oxidation. The catastrophic fires in Indonesia in 1997–1998 caused one of the largest carbon emission events recorded globally, releasing approximately 0.87 gigatons of carbon or about 14% of the average annual global fossil fuel emissions in the 1990s. These findings highlight the urgent need to reduce peatland vulnerability to fire to mitigate carbon loss and environmental damage (Hoscilo et al., 2011).

From 2001 to 2018, peatlands in Sumatra and Kalimantan burned at rates nearly five times higher than non-peatland areas, with a 37% and 48% decline in burned area between 2001–2007 and 2008–2018, respectively. Fires predominantly occurred in peat swamp forests that were previously forested in 1990 but later altered by land-use changes. Kalimantan experienced higher fire frequency and more repeated fires than Sumatra. These results demonstrate that land-use and land-cover changes strongly affect fire regimes in Indonesian peatlands. Without substantial reductions in fire incidence, significant loss of peat swamp forests in these regions is likely within decades (Vetrita & Cochrane, 2020).

Tarigan (2016) show a significant impact of land cover change, particularly the expansion of oil palm plantations, on flood frequency in the Batanghari watershed in Jambi Province, Indonesia. Using Landsat imagery and the CLASlite module to analyze forest cover change and oil palm expansion, the study found that large forest areas were converted to other land uses, including oil palm plantations. It also observed a sharp increase in flood frequency in the watershed, driven by rapid forest cover loss.

The rapid expansion of palm oil plantations in Indonesia is driven by rising global demand due to population growth, higher incomes, and the increasing role of emerging economies. Health awareness favoring vegetable oils with lower trans fats and the growing need for biofuels as a climate solution also contribute to this growth. By 2050, Indonesia may require an additional 18.65 to 45.57 million hectares of palm oil plantations, creating a trade-off between expansion and environmental conservation. Expansion is expected mainly in Sumatra and Kalimantan, which have historically seen over 90% of growth, with Papua emerging as a significant new area due to limited available land in the other regions (Xin et al., 2022).

The primary cause of deforestation in Indonesia, especially on peatlands, is the expansion of plantation-based agriculture, particularly monoculture crops like palm oil and rubber. This expansion is supported by various policies and transmigration schemes, leading to the conversion of forests into agricultural land. Additionally, the drainage of peatlands for farming dries out the upper peat layers, making them more susceptible to fires and causing significant greenhouse gas emissions. Periodic fires and the growth of scrub vegetation resulting from human activities such as drainage, deforestation, and peatland conversion also contribute to peatland deforestation (Lupascu et al., 2023).

Ma'rufah et al., (2023) projects that without conservation measures, oil palm plantations will become the dominant land cover in Jambi Province by 2100, occupying about 30% of the area. Expansion of oil palm plantations has led to land cover change, deforestation, and increased flooding in some areas. Thus, conservation efforts and strong policies are essential for sustainable land-use management in the region.

However, conservation initiative may lead to conflicts in the area. Frequent conflicts between rural communities and palm oil companies in Indonesia, largely driven by collusion between authorities and companies that undermine conflict resolution mechanisms. Protests are often directed at local governments rather than companies, as communities first try direct

negotiation with companies but resort to demonstrations when ignored. NGOs play a crucial role in supporting communities and raising awareness nationally and internationally. The research also shows that rural communities rarely use legal systems or RSPO complaint mechanisms due to challenges like proving land ownership, high costs, and perceived judicial corruption. Instead, they rely on local authorities for mediation, which is often ineffective due to collusion. Key challenges include limited access to justice, collusion hampering conflict resolution, unfair profit-sharing in plasma schemes, limited legal power despite land claims, and the economic dominance of palm oil companies, all contributing to communities' weak bargaining position and limited success in resolving disputes (Berenschot et al., 2022).

Novira et al., (2019) observe the significant influence of political policies, large-scale external investment, and economic shifts on land use change in Indonesia. Decentralization has granted regional leaders broad authority, often leading to the legalization of previously illegal land use changes.

Nevertheless, conservation must still be pursued considering Indonesia's mangrove forests store a large amount of carbon (3.14 PgC) and play a key role in climate change mitigation. Preventing mangrove deforestation in Indonesia could reduce 10–31% of current land-use emissions. In Indonesia, mangrove conversion accounts for 42% of global emissions from coastal ecosystem destruction. (Murdiyarso et al., 2015).

Global peat carbon stocks are estimated to range between 469 and 486 gigatons (Gt), with the best estimate at approximately 480 Gt. Tropical peatlands contain between 14% and 19% of the global peat carbon stocks, with the best estimate around 17%. The region holding the largest proportion of tropical peatland volume is Southeast Asia, with Indonesia accounting for the largest share of tropical peat carbon (57 Gt, 65%), followed by Malaysia (9 Gt, 10%) (Page et al., 2011).

Ariesca et al., (2023) found that relocating oil palm plantations from peatlands to mineral soils in Kalimantan, Indonesia, could reduce greenhouse gas emissions by up to 65.43% over 25 years and increase fresh fruit bunch yields by 17.16% annually. It also highlights potential financial benefits for the government and emphasizes the importance of collaboration between policymakers and stakeholders to support a sustainable palm oil industry.

Furthermore, there are also negative perceptions of palm oil products, result from deforestation-related issues. This concern has attracted both national and international attention, particularly regarding biodiversity loss, greenhouse gas emissions, and violations of indigenous rights. As a result, many countries and global consumers have begun to demand more sustainable and transparent production practices. However, some argue that such perceptions may also be influenced by negative campaigns driven by trade competition, particularly from Western countries that are less competitive in palm oil production. For example study by Lieke et al., (2023) mention that German consumers associate palm oil and its cultivation with predominantly negative perceptions, particularly due to environmental concerns such as rainforest deforestation and ecological degradation. They also link palm oil to issues including poor labor conditions, social displacement, and health risks.

Land Use and Carbon Pricing Policy

Studies on carbon pricing policies in the land-use change sector remain limited, especially in Indonesia, indicating a research gap that warrants further exploration. While land-use and deforestation have been widely studied, there is still a lack of research on how carbon pricing can effectively address deforestation and emissions within this sector.

Carbon tax can be an effective policy option for reducing emissions, with its impact depending on tax design and how the generated revenue is used. It also shows that carbon tax can yield environmental benefits, such as reducing local pollution, and may positively influence economic growth and employment (Baranzini et al., 2000). On the other hand, the performance of Emissions Trading Systems (ETS) varies across jurisdictions. Key success factors include institutional learning, careful administration, and proper carbon revenue allocation (Narassimhan et al., 2018).

According to Green (2021), carbon pricing policies have a limited impact on reducing greenhouse gas emissions, with overall annual reductions typically ranging from 0% to 2%. Carbon taxes tend to be more effective than emissions trading schemes (ETS), including the EU-ETS, which is the oldest and largest ETS but shows limited annual emission reduction effects. Overall, the evidence suggests that carbon pricing has only a modest impact on emission reductions

In the USA, implementing carbon tax would significantly impact agriculture and land-use emissions. It would increase production costs for crops like corn and soybeans, reduce farmers' income, and lower exports of key commodities. (Dumortier & Elobeid, 2021).

Dissanayake et al., (2020) show that both carbon taxes and ETS encourage renewable energy adoption. The research concludes that carbon tax is a more practical option for developing countries like Indonesia in the short to medium term, as it has less impact on economic sectors and employment compared to fuel taxes. However, implementing ETS in Indonesia faces political and economic challenges.

Another study find that carbon pricing is an effective tool to reduce greenhouse gas emissions, with options including carbon taxes, cap-and-trade systems, emission reduction credits, clean energy standards, and fossil fuel subsidy reductions. Examples from countries like Canada, Sweden, Norway, Germany, and the USA show successful implementation of these policies. Linking cap-and-trade systems across regions can lower overall costs, reduce market power, and stabilize prices, but faces challenges such as policy harmonization, price uncertainty, and administrative complexity. Overall, these diverse carbon pricing mechanisms encourage emission reductions and the adoption of clean energy (Aldy & Stavins, 2012).

Strategy to improved economic incentive structures can lead to more substantial reductions in deforestation-related emissions in Indonesia. Under a scenario where the national government offers voluntary incentives at an international carbon price of \$10/tCO_2e, emissions could be reduced by 8% compared to the reference scenario. However, by implementing more robust mechanisms, such as a cap-and-trade system or a tax-and-subsidy program, emission reductions could reach up to 26%, while also generating a budget surplus of approximately \$1 billion annually (Busch et al., 2012).

Key challenges in reducing emissions from land use in Indonesia include: ambiguities in the scope and definition of "forest", issues surrounding land ownership and tenure rights, the complexity of managing peatlands, especially whether they should be classified within or outside forest categories for intervention targeting, and the difficulty of balancing equity and efficiency along the forest transition curve. Additionally, ensuring fair and efficient benefit-sharing mechanisms across various stages of tree cover transition, such as conservation, degradation, and restoration, remains a significant concern (van Noordwijk et al., 2014).

Particularly in the context of peatland conservation, carbon pricing can be financially more beneficial than converting land to oil palm or rubber plantations. While carbon revenues from plantation-based land uses may exist, they are generally lower than potential revenues from conservation, and still fall below the average carbon market price. Combining carbon pricing mechanisms with payments for ecosystem services could enhance the financial attractiveness of peatland conservation and contribute to reducing carbon emissions (Pertiwi et al., 2022).

The reviewed literature collectively illustrates the persistent tension between economic development and environmental conservation in the context of land use, deforestation, and carbon emissions, especially in Indonesia and Southeast Asia. Economic expansion through plantation development, infrastructure, and transmigration programs has driven widespread land-use change, resulting in biodiversity loss, increased emissions, and degradation of critical ecosystems like peatlands and mangroves. Various initiatives have been introduced to address these challenges, ranging from non-market policies such as forest moratoriums to market-based approaches like carbon pricing. However, both approaches face significant obstacles, including weak enforcement, institutional limitations, and conflicting economic interests, which have hindered their overall effectiveness. The evidence underscores the dominance of agricultural expansion, especially oil palm, as the primary driver of deforestation, facilitated by both formal policies and informal power networks. Moreover, governance failures, such as corruption, unclear land tenure, and collusion between local elites and corporations, continue to undermine sustainable land management and equitable resource use.

A promising direction for future research and policy is the integration of carbon pricing mechanisms specifically adapted to the land-use sector, particularly in peatlands and primary forests. Although the effectiveness of carbon taxes and emissions trading systems varies across contexts, the land-use sector presents distinct opportunities. Evidence shows that combining carbon pricing with payments for ecosystem services can generate higher financial returns than plantation-based land uses in peat-rich areas. Developing hybrid models that reflect regional forest conditions, land tenure systems, and community-based incentives could address existing gaps in the literature and support practical solutions to align development and emission reduction goals. This approach not only fills a methodological gap in current carbon pricing literature but also contributes practical solutions for reconciling development goals with emissions reduction. It could also enable Indonesia as a leader in land-based climate policy innovation.

CONCLUSION AND RECOMMENDATION

From the Scopus database, a total of 929 publications that discuss about Carbon Pricing Analysis in the Land Use Change Sector and Low Carbon Development Planning were identified. These publications were published between 2003 and 2023 and are all in English. The subject areas include Environmental Science, Social Sciences, Economics, Econometrics and Finance, as well as Multidisciplinary fields.

Trend analysis indicates a significant increase in the number of publications year by year. More recent research topics relate to blue carbon, carbon neutrality, carbon tax, climate change mitigation, wildfire, urbanization, and oil palm plantations. In addition, methods such as

random forest, computable general equilibrium, and scenario simulation have increasingly been applied in carbon pricing studies.

The most prominent and frequently discussed topics include Land Use Changes, Deforestation, Climate Change, Carbon Emissions, Carbon Sequestration, and the REDD+ mechanism (Reducing Emissions from Deforestation and Forest Degradation). However, several topics are relatively underexplored, such as, driving factors of land use change, Clean Development Mechanism (CDM), soil carbon, soil organic matter, tropical peatland, shifting cultivation, land use and land cover (LULC), adaptation, carbon leakage, and greenhouse gas emissions from the agriculture and forestry sector (FASOMGHG).

Economic activities like industrial expansion, infrastructure, and resource extraction tend to degrade the environment through deforestation, pollution, and biodiversity loss. Studies show that while economic growth increases CO_2 emissions, the use of renewable energy and sustainable forest management can reduce emissions. Policies promoting low-carbon economies, renewable energy adoption, and forest conservation are essential for balancing economic development with environmental sustainability.

Land use change, especially deforestation driven by agricultural expansion and plantation development (notably oil palm), poses a significant threat to forests in Southeast Asia. Indonesia, in particular, experiences substantial forest loss with serious implications for carbon emissions and climate change. Despite moratoriums and policies aimed at reducing deforestation, challenges remain due to conflicting policies, poor enforcement, illegal logging, and regional disparities. Community-based forest management, stronger law enforcement, and fiscal incentives are recommended to enhance forest governance and reduce emissions.

Peatlands and mangroves are critical ecosystems in the region, storing vast amounts of carbon and providing vital ecological services. However, their conversion to plantations and aquaculture leads to high greenhouse gas emissions and biodiversity loss. Fire outbreaks in peatlands, exacerbated by drainage and land-use changes, further accelerate carbon release, contributing significantly to global emissions. Conservation measures, combined with sustainable land management and economic incentives like carbon pricing and REDD+ payments, are necessary to protect these ecosystems and mitigate climate impacts.

Finally, land use change is influenced by a complex interplay of economic, social, and political factors. Successful environmental management requires a multidisciplinary approach that incorporates local community involvement and equitable governance in forest and land use management. Notably, research on carbon pricing policies in the land-use change sector remains limited, highlighting a critical gap that warrants further investigation.

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