The status of bamboo research and development for sustainable use in Indonesia: A systematic literature review

The status of bamboo research and development for sustainable use in Indonesia: A systematic literature review

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Abstract. The current global situation of bamboo utilization has shifted from traditional to modern bamboo, along with improved technology and innovations. However, the literature on bamboo research and development in Indonesia is still minimal and fragmented. Moreover, it has not yet clearly seen the strategy and direction of future utilization and its sustainability. Therefore, it is urgent to know the current status of bamboo research and development, especially its sustainable use. A systematic literature review was carried out on the research and development of bamboo in Indonesia, examining and comparing publications from both academic and professional works of literature in the period 2001 to 2021. This study was conducted by building insights from past reviews and initial scoping analysis of two decades of bamboo R&D. The findings of this study build upon the research and efforts on the social-cultural, economic, and ecological aspects underpinnings of bamboo utilization and development. Furthermore, the typology and other supporting factors that have already been carried out will be proposed to help connect fragmented and detached aspects into an integrated strategy and direction of research and development. Finally, future orders for progressing and sustainable bamboo utilization and development in Indonesia are identified.

1. Introduction

The current global situation of bamboo utilization has shifted from traditional to modern bamboo, along with improved technology and innovations. Currently, the development of bamboo globally and in Indonesia, in particular, is experiencing an increase [1]. The use of bamboo as an environmentally friendly material, both as a construction material, furniture, and household appliances, as a food ingredient, and even as a source of clothing fiber and many more uses [2–7] The importance of supporting the research and development aspects of innovative technology is one of the determinants of the success and success of bamboo in China [8]. What is the situation and condition of bamboo research and development in Indonesia? It is crucial to see to what extent the results of the study that has been carried out and published in international journals and proceedings. Boukhatem [9] stated that the

advantage of publishing research results in scientific journals is that our research will be read, recognized, and quoted by scientists and other researchers with the same interests and fields of science as us. Publishing our scientific writings in reputable journals will add value to our research, results, and recommendations, especially for policymakers [9].

However, the literature on bamboo research and development in Indonesia is still minimal and fragmented. It has not yet seen the strategy and direction of future utilization and its sustainability. Moreover, it is urgent to know the current status of bamboo research and development, especially in its sustainable use. Furthermore, reviewing and analyzing bamboo research and development in Indonesia over the past two decades is necessary. The study was carried out using a systematic literature review on the research and development of bamboo in Indonesia, examining and comparing publications from academic and professional literature works from 2001 to 2021.

The literature reviews were conducted by building insights from past reviews and an initial scoping study of two decades of bamboo research and development. The purpose of the study was to analyze and find the research and efforts on the social-cultural, economic, and ecological aspects underpinnings of bamboo utilization and development, as the current research status of bamboo in Indonesia, and to identify the existing research gaps. The study results can be used as information and reference in policy making and implementation practices and further formulate future bamboo research and development needs in Indonesia.

2. Methods

This study has taken two approaches to determine Indonesia's current bamboo research and development status. The first approach used bibliographic software analysis of Publish and Perish (PoP) and VOSviewer. Both were used to build network links and map the research keywords in the published paper's titles and abstracts. The second approach of this study was carried out by systematic literature reviews (SLR) that conducted further analysis in the selected journals by identifying bamboo research topics that had been carried out in Indonesia for two decades.

2.1. Database of publications for analysis

Database publications were harvested from several existing internet base search engines' academic papers. The first approach uses journals searched and selected from the Google Scholar and Crossref web databases. The second approach of the SLR analysis used three database sources of publications taken from Google Scholar, Science Direct, and Mendeley Discovery (Figure 1).

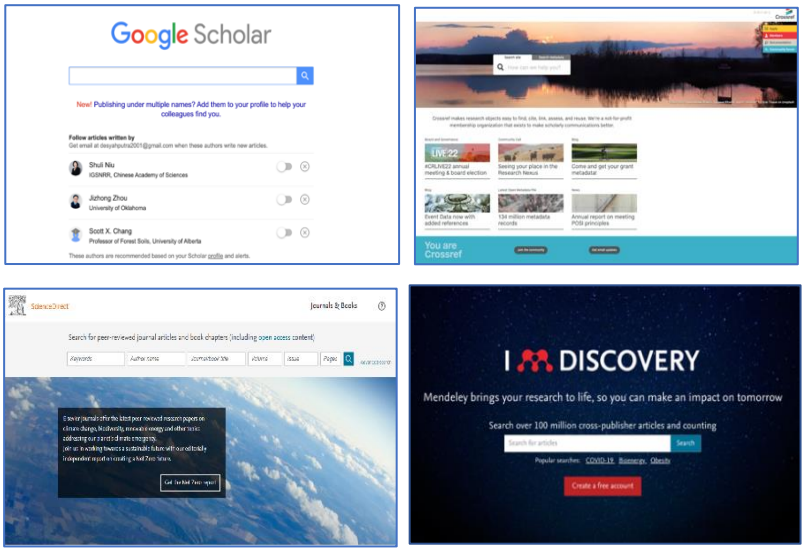


Figure 1. The preview of the web database as a search engine to collect publications

2.2. Mapping and visualization of bamboo's research and publication in Indonesia

Keyword mapping of Indonesian bamboo research, network visualization, history, and research focus has been carried out for two decades in Indonesia. The process was carried out using a combination of two bibliography analysis software as follows.

2.2.1. Search and select publications with the software Publish or Perish (PoP)

Publish or Perish is a software program retrieves and analyses academic citations [10]. This software is designed to help individuals or academics to find and analyze the sources of information needed from various publication database sources to obtain citations for research that has been carried out. The database sources were used for this approach, namely *Google Scholar* and *Crossref,* using the keyword of "*bamboo Indonesia*"; each search result on the two search engines is stored in the "RIS" extension file. The RIS file is a bibliographic citation file saved in a format developed by Research Information Systems (RIS).

2.2.2. Map and visualize with VOSviewer software

VOSviewer is a program for creating and visualizing bibliometric networks. These networks can be built using citation, bibliographic coupling, co-citation, or co-authorship relationships and include journals, researchers, or individual publications. *VOSviewer* also has text mining functionality for creating and visualizing co-occurrence networks of important terms extracted from scientific literature [11]. Developed by the Centre for Science and Technology Studies at the University of Leiden, *VOSviewer* works with bibliographic formats from Web of Science files, Scopus files, PubMed files, RIS files, and Crossref JSON files.

2.3. Systematic Literature Review (SLR) analysis

This study was conducted to find out the scope of research and publications that have been published related to Indonesian bamboo, and a systematic literature review was carried out in this study. Systematic literature review (SLR) is a research design through an approach that is carried out by systematically synthesizing existing research evidence and publications in terms of searching research articles, critical appraisals, and synthesizing research results to answer a research question. The SLR approach is carried out for various purposes, including identifying, reviewing, and interpreting all available research with particular topics of interest with relevant research questions. The position of the systematic literature review methodology in the research methodology can be described as an onion slice, as shown in Figure 2.

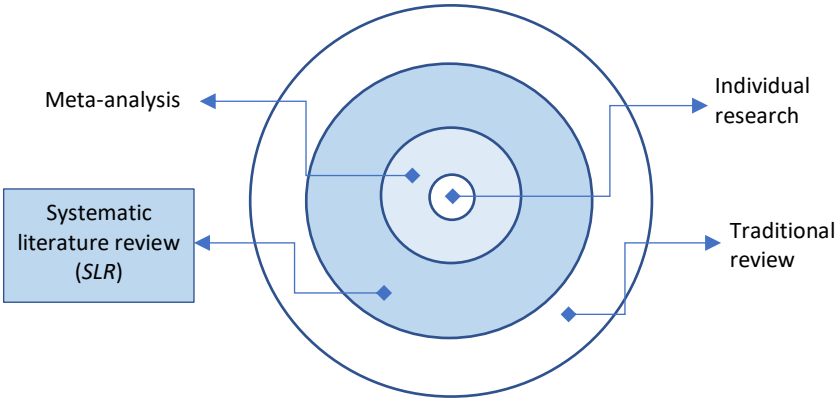


Figure 2. An onion slice figure describes the position of the systematic literature review methodology

2.3.1. Framework and stages

The stages in conducting a systematic literature review are: (1) defining the scope of the topic to be reviewed; (2) identifying relevant database sources; (3) conducting a literature review; (4) making a literature review and synthesis; (5) analyzing and writing a review. This study was conducted by building insights from past reviews and initial scoping analysis of two decades of bamboo research and development in Indonesia by examining and comparing publications from academic and professional works of literature in the period 2001 to 2021.

2.3.2. Database and keywords

The database sources used in this research are international journals and international proceedings indexed by Scopus. Searches for international journals and proceedings were conducted on the Google Scholar, Science Direct, and Mendeley Discovery websites using the keywords: "Indonesia bamboo" and “Indonesia and bamboo".

2.3.3. Criteria for inclusion and exclusion

Before conducting the searching and screening stages, a determination of criteria for inclusion and exclusion is carried out as a justification in sorting publications that will be further analyzed. The criteria for inclusion and exclusion applied in this study as detailed in Table 1.

Table 1. Criteria for inclusion and exclusion

Criteria	Inclusion	Exclusion
Topics and issue	All research on bamboo and its development in Indonesia covers all topics and themes	Unrelated research on bamboo topics and themes related to bamboo in Indonesia.
Study Design and Publication Type	All research related to bamboo in English and published in	Not in English and not published in international journals and proceedings
Publication Years	Journal and proceeding of the last 20 years from 2001-2021	Journal and proceeding published before the year 2001
Language	English	Not in English
Literature Type	International journal and proceedings	Non-research articles.

2.3.4. Systematic searching strategies

The process of systematic searching strategies is carried out through the search and screening stages, followed by selecting eligible journals according to the criteria that have been made to obtain selected papers for systematic review analysis, as presented in Figure 3. From searches in three database sources Science Direct, Google Scholar, and Mendeley Discovery, with the keywords "bamboo Indonesia", "Indonesia bamboo" and "Indonesia and bamboo" on the first step of the search obtained 2125 papers. After being sorted based on predetermined criteria, an exclusion process was carried out so that 1872 papers were obtained from three database sources. After further examination, the final stage is to exclude duplicate journals unrelated to bamboo research in Indonesia. In the last step, based on inclusion criteria, 234 papers were selected, which will be reviewed and further analyzed to determine the focus and topic of the research.

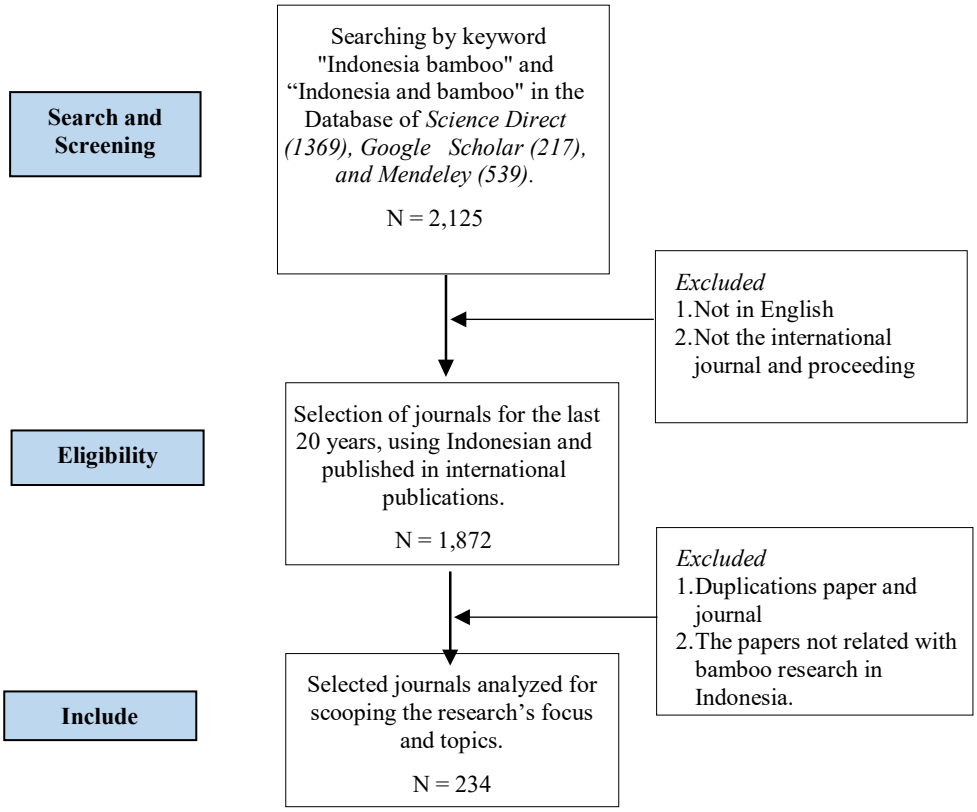


Figure 3. The flow diagram of process on papers selections for SLR analysis

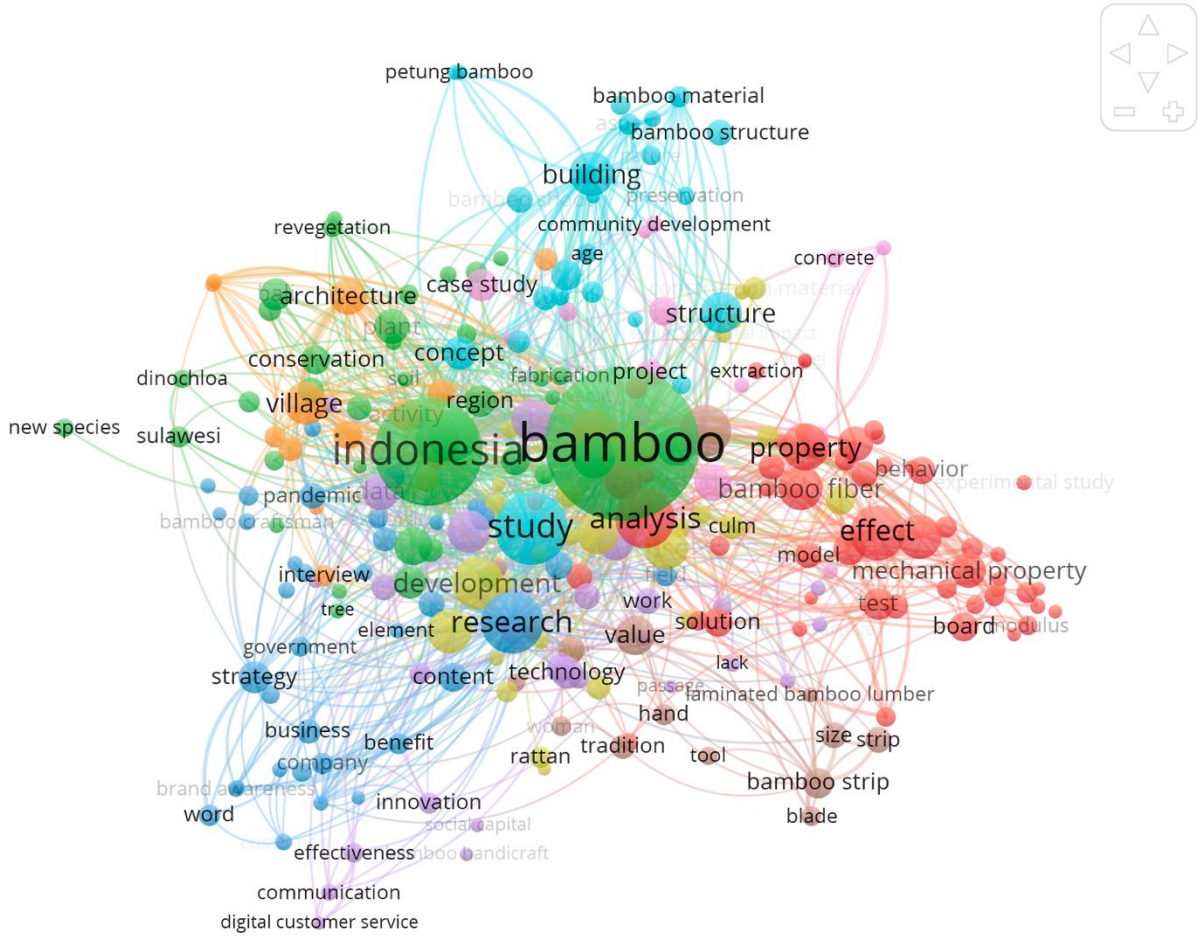
3. Result and Discussion

3.1. Visualization of clusters and links-network bamboo research in Indonesia

One visualization result of bibliometric data processing using VOSviewer is the mapping of terms or keywords (co-occurrence maps). The visualization is produced by mapping keywords and terms taken from titles and abstracts from the selected paper-paper database. Figure 4 is the result of a visualization showing the link network of keywords bamboo research carried out in Indonesia in two decades, divided into nine clusters in different colors. The size of the letter display and the circle indicate the number of links-networks built up and show the intensity of the frequent co-occurrence of the keyword.

Figure 4 shows that the keywords; bamboo and Indonesia are most commonly occurring and are in one cluster. The largest cluster was cluster 1, consisting of 57 items or interrelated keywords/terms. Keywords; analysis, mechanical property, effect, and treatment are words with many link networks and often appear in titles and abstracts. Further analysis showed Cluster 1 consists of topics on basic research such as mechanical properties and characteristic physic of bamboo.

While cluster 2 was dominated by keywords; bamboo and Indonesia, other terms frequently used were bamboo species, community, and knowledge. Cluster 2, in green color, is a group with the topics of bamboo resources and related to ecological aspects. The keywords; research, benefit, and strategy were dominated in cluster 3 (dark blue color). Cluster 3 represents the research related to aspects of bamboo management. In general, from the visualization of grouping keywords/terms that are often occurred from the publication database, it can be seen that clusters 4-9 describe keywords/terms that are closely related to the use and utilization of bamboo.



Cluster 1	Consist of 57 items, keywords; analysis, mechanical property, effect, treatment
Cluster 2	Consist of 42 items, keywords; bamboo, Indonesia, community, bamboo species, knowledge
Cluster 3	Consist of 36 items, keywords; research, strategy, benefit, business
Cluster 4	Consist of 32 items, keywords; use, process, development, product
Cluster 5	Consist of 27 items, keywords; application, data, technology, innovation
Cluster 6	Consist of 24 items, keywords; study, building, structure, sustainability, sustainable materials
Cluster 7	Consist of 16 items, keywords; activity, environment, village, architecture
Cluster 8	Consist of 15 items, keywords; construction, value, bamboo strips, farmer
Cluster 9	Consist of 15 items, keywords; building material, project, com-dev, rural area

Figure 4. The visualization of clusters and links-network bamboo research in Indonesia

3.2. Visualization of density and focus of bamboo research in Indonesia

VOSviewer has a function in processing text and then visualizing and overlying keywords from the bibliographic database. The analysis also produced visualizations related to the density and focus of bamboo research in Indonesia. As shown in Figure 5 the density and stress of research on bamboo that has been widely carried out in Indonesia can be known. The visualization of density or emphasis is also drawn on clusters, so it can be seen that the part of the research is still rarely carried out and vice versa.

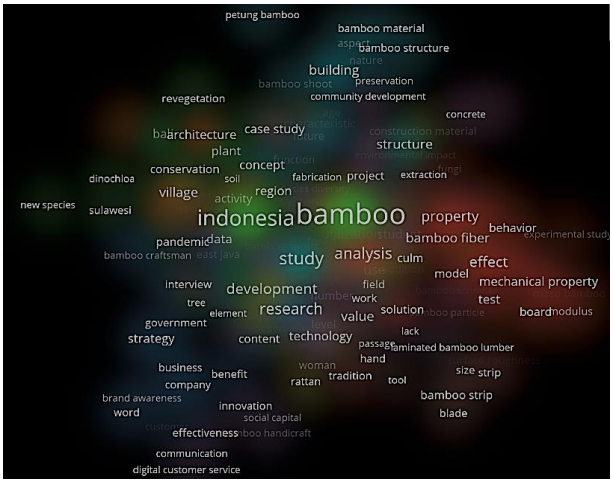


Figure 5. The visualization of density and focus of bamboo research in Indonesia

3.3. Visualization of overlay of the bamboo research history and year of publication

The third visualization resulting from the bibliometric's VOSviewer analysis of the research journal database is an overlay that shows the history of the research and the year of its publication. Overlay visualization shows traces of the research history, showing the latest research in bright yellow. At the same time, previous studies are depicted in darker blue and green colors, as shown in Figure 6.

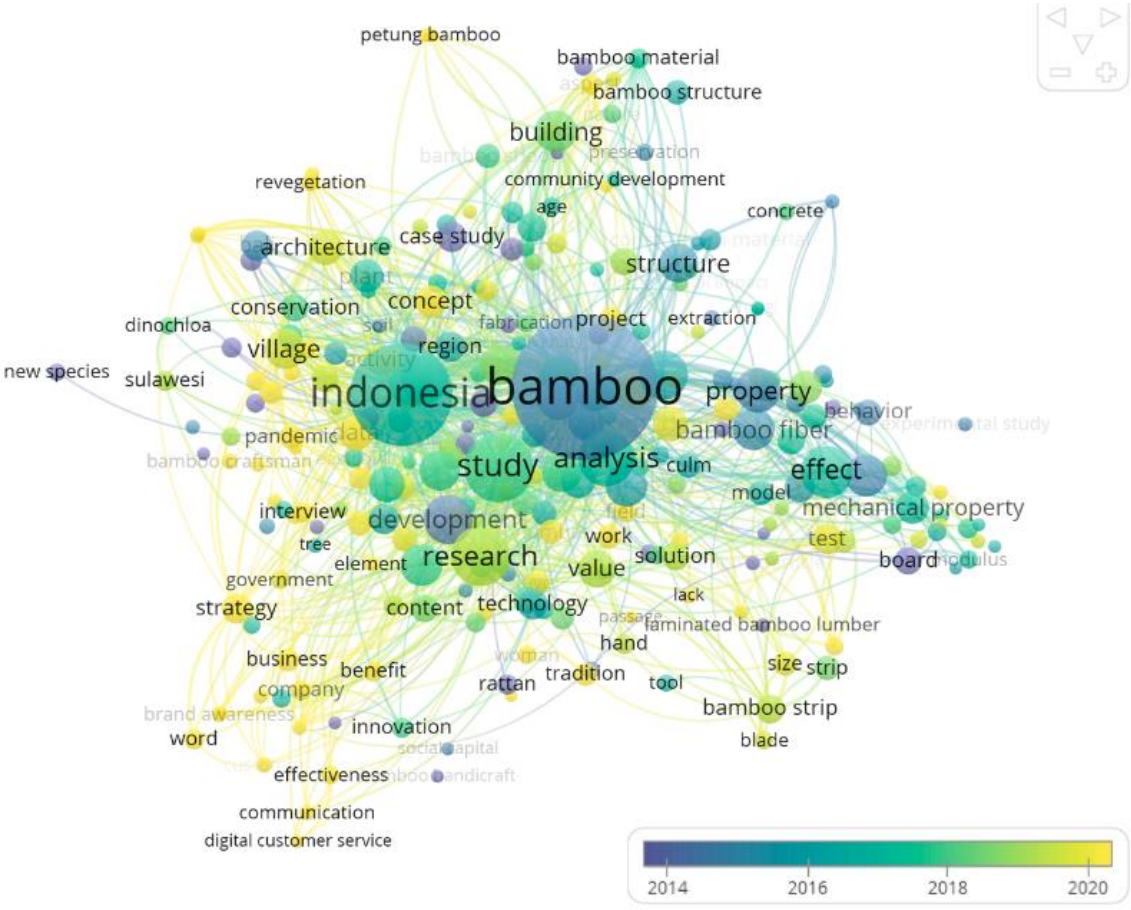


Figure 6. Visualization of overlay history and year of publication

The latest research has begun to be seen developing in cluster 2 (bamboo, Indonesia, community, bamboo species, knowledge), cluster 3 (research, strategy, benefit, business), and cluster 7 (activity, environment, village, architecture). From the visualization, it can also be seen that bamboo research publications in Indonesia have continued to increase from the year 2014. Several new research was published between 2018-2020, shown by the lines and dots of bright yellow drawn more and surrounding the blue and green color.

3.4. Sustainability aspects of bamboo research in Indonesia

This study still uses bibliometric analysis with VOSviewer to determine the extent of sustainability aspects in the studies. We research emerging keywords related to sustainability aspects. Two terms that arise from the analysis of the text contained in the title and abstract of the publication are the words sustainability and sustainable material, as shown in Figure 7. Both terms appear in cluster 6 together with the term; study, building, and structure. It can be seen that links related to these two terminologies do not often occur with few link networks. Therefore, it can be said that the sustainability aspect has not been clearly illustrated in the bamboo research carried out in Indonesia for two decades.

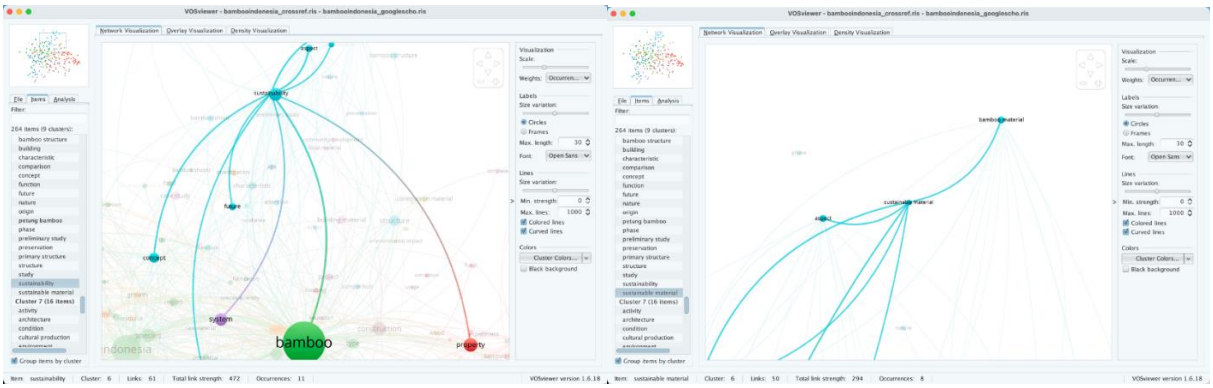


Figure 7. The aspect of sustainability of bamboo research in Indonesia

3.5. The status of Indonesia's bamboo research in two decades

The second approach, SLR analysis, was conducted to learn more about the status of Indonesian bamboo research carried out in two decades, with the process stages previously outlined in Figure 3. Systematic literature analysis to determine the study's scope, focus and topic was carried out on 234 papers that had been sorted from three sources of online publication databases.

3.5.1. Number of samples and year published

Research publications on bamboo in Indonesia that were published in international journals and proceedings for two decades, starting from 2001–2021, found as many as 234 publication titles, as shown in Figure 8. It can be seen on the graph that the increase in the number of published studies began to increase significantly starting in 2014. The result was in line with the visualization resulting from the bibliometric analysis of VOSviewer in Figure 6.

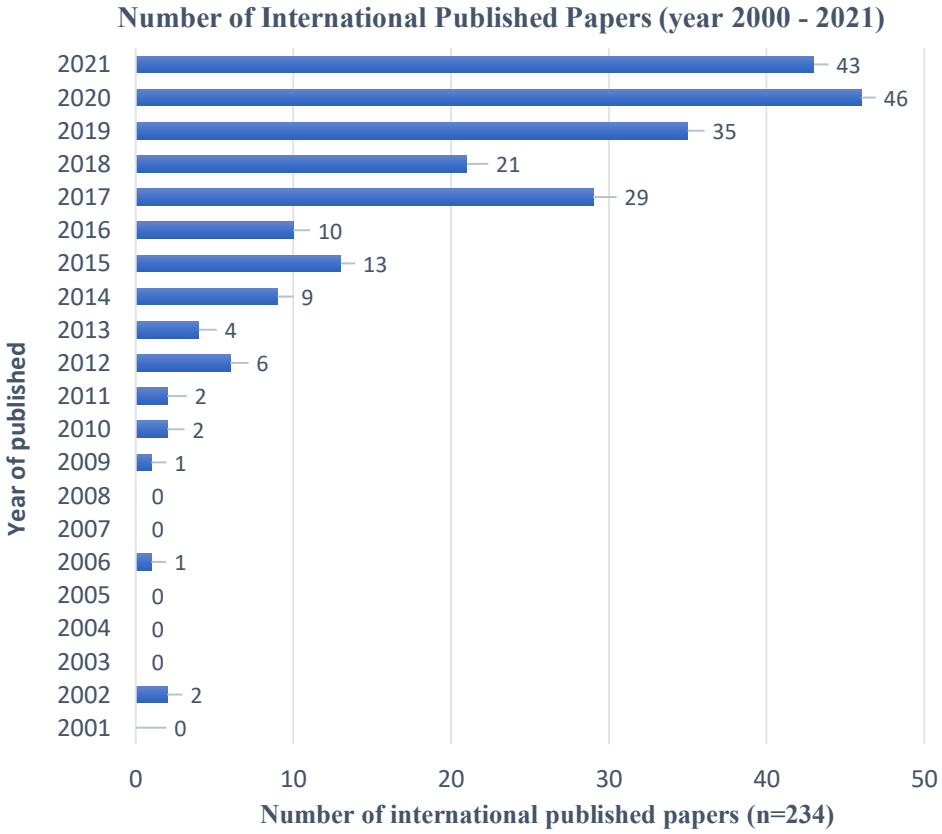


Figure 8. The number of international journals and proceeding on bamboo research and development in Indonesia from the year 2001 – 2021

3.5.2. Themes and topics of journals

From conducted SLR Analysis showed that there have been many topics and research focus related to the use of bamboo in Indonesia, which have been carried out and published in two decades from 2001-2022. The most published papers on bamboo utilization in Indonesia were on construction, biocomposite, and properties, as shown in Figure 9. The results of the SLR analysis related to the theme, topic, and focus of the research carried out are in line with the visualization produced by VOSviewers in Figure 4, mapping of terms/keywords that often occur, and Figure 5, the intensity of the research focus. Research focusing on properties and biocomposite dominated, followed by topics related to bamboo resources (diversity and distribution).

The research that has been carried out on bamboo anatomy is related to the identification and characteristics of commercial bamboo [12], the finding of new types of bamboo in the lesser Sunda Islands [13], and the identification of types using an online expert system [14]. At the same time, the ecological aspect is research related to soil factors and bamboo populations [15]. Research on bamboo species' diversity and distribution in Indonesia has been relatively widely carried out [16,17] The diversity of bamboo types published in international journals were the diversity of bamboo species on the islands of Sumatera [18–20], Java [21–24], Bali [25–27, Nusa Tenggara [28], and Sulawesi [29–31]. Meanwhile, research specifically publishes the findings of new species and genera in Indonesia, where the new record of species *Dinochloa malayana* [32] and the new species of climbing bamboo from Sulawesi [31]. The genetic diversity of several species of Indonesian bamboo has also been researched and published. Research on genetic diversity was carried out with type identification using molecular genetic markers and random amplified polymorphic DNA (RAPD) markers [21,33,34].

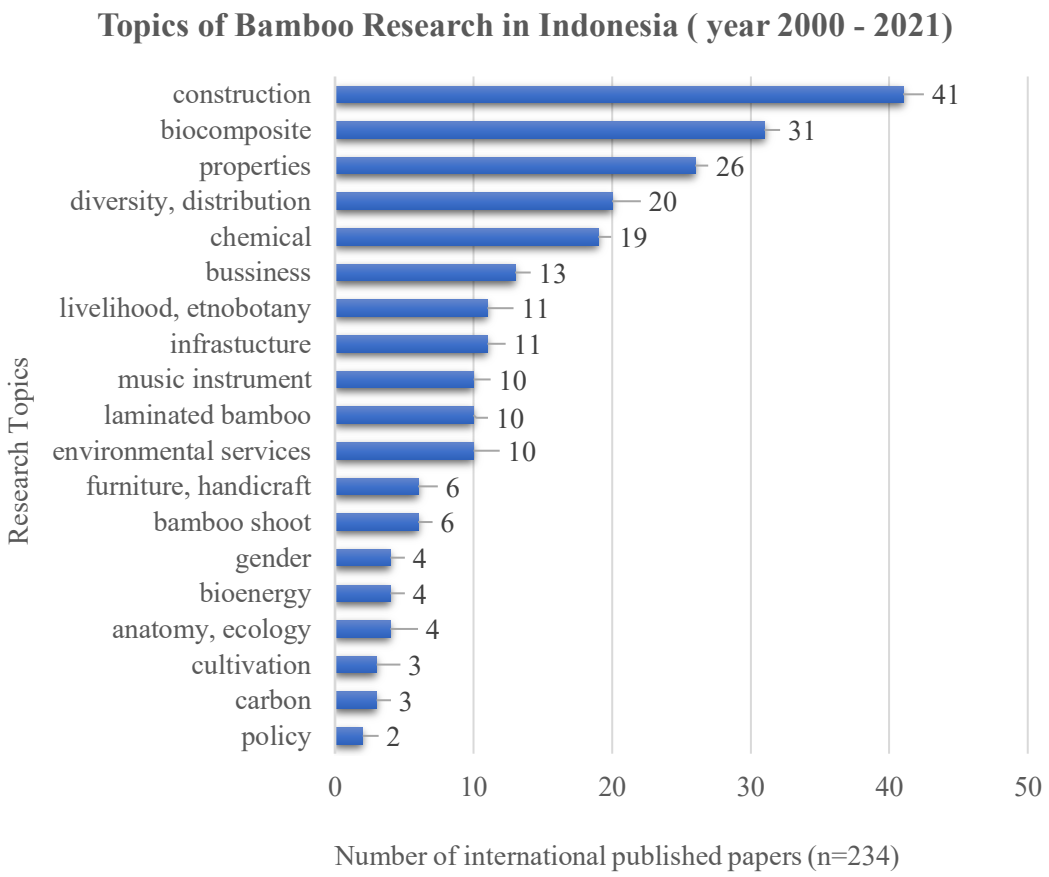


Figure 9. The topic of research and development of bamboo in Indonesia from the year 2001–2021

Topics related to bamboo cultivation systems are essential in supporting the development of bamboo; however, research on this matter in Indonesia is still minimal. There were only three international papers published with topics related to cultivation that have been carried out the application and trial of fungi on bamboo growth and the research of rhizobacteria from shallots to help the growth of bamboo roots [35] and the application of *Xylanolitic* fungi in *Bambusa sp.* litter composting [36]. In addition, one paper presented the micropropagation of *Dendrocalamus asper*, one of the most widely cultivated commercial varieties of bamboo [37].

Bamboo is a natural resource closely related to the livelihood and culture of the Indonesian people. Therefore, encourages research related to bamboo's local wisdom and ethnobotany in several areas as follows; West Java [24,38], Bali [26,27,39], Sulawesi [40], and East Nusa Tenggara [41] Research topics on bamboo related on gender in general talk about the role of women in bamboo development, particularly at the household level [41–44]. Other aspects of culture were the study and publications on traditional and modern musical instruments made from bamboo. One of Indonesia's traditional bamboo music instruments has been recognized as an intangible world cultural heritage by UNESCO (United Nations Educational, Scientific and Cultural Organization) [45]. Angklung is a bamboo musical instrument made from two to four bamboo tubes suspended in a bamboo frame inscribed in 2010 on the representative list of the intangible cultural heritage of humanity. The research and published paper on angklung discussed acoustic analysis, design engineering, and species materials, as well as preserving angklung as a global cultural heritage, especially in Indonesia [46–51]. Papers on other bamboo musical instruments in Indonesia also published both traditional musical instruments such as *karinding* and *bundengan* [52,53], as well as modern musical instruments such as guitars and violins [54–56].

Regarding the theme of bamboo utilization, the published journals published research results focused on bamboo as a construction. There were identified 41 papers on the topic of bamboo construction material, covering both traditional buildings [49,57–59] and modern building architectural designs [60–62]. In addition, journals focused on bamboo material as an environmentally friendly material, a renewable material [63–65], earthquake-resistant buildings, and also the use of bamboo as a building material after a disaster [66–69] were also published.

The second most published papers were focused on biocomposite topics. There were identified 31 papers published. The research and development of biocomposites consisted of a study on bamboo fibers for various industrial products [70,71], pulp [72,73], biochar [74], and some species of bamboo-activated carbon research [75–81], as natural-fiber materials [82–84]. The topic of bamboo properties was the third most published paper. There were identified 26 papers covered the aspects of; properties and mechanical properties of several species of bamboo [85–91] as well as the properties of bamboo products as a building construction material [92–97]. The research on bamboo as an infrastructure material, namely; bridges [98, 99], hardeners or foundation bases of roads [100–102], and walls for wave and water blocks [103–105] was also published. Another research topic still related to construction and infrastructure is engineered bamboo. Several publications on laminated bamboo were published as one of the products of engineered bamboo [106]. The papers of laminated bamboo were focused on the processing of several bamboo species (*B.arundinaceae, G.apus, D.asper, G.scortechinii*) into laminated products [85,107], as well as the use of various kinds of glue [108], and development of laminated bamboo into other products such as ships [109–111], boards [93,108]and blocks [112].

The research topic on the use of bamboo shoots that has been carried out is the nutritional and nutrient content and other research related to its processing technology [113–117]. The aspect of utilizing bamboo as a renewable energy source is one of the research topics carried out in Indonesia. In general, the research reviewed the potential and prospect of bamboo development as bioenergy, and one paper reports on the development of power plants with bamboo biomass power [118–120]. Other publications on bamboo research also covered the role of bamboo for environmental services, ecological function, and carbon sequestration. The ecological aspects of bamboo research covered the position of bamboo for riverbank protection, soil, and water conservation [121,122], land restoration [123], and post-mining revegetation [124]. Another role in environmental services was bamboo carbon research focuses on carbon stocks stored on bamboo stands in several regions in Indonesia [125,126].

The research related to business aspects that have been carried out includes aspects of the value chain [127,128], business models of the creative economy of the household industry, business analysis, and feasibility studies, as well as business strategies for bamboo development [129–133]. There was a lack of research topics focused on bamboo development strategies and regulatory policy support in Indonesia. Only two international publications discussed the strategy and regulation support; the first journal presented bamboo networks and their impact on the political economy of the Southeast Asian region, comparing Indonesia and the Philippines. The other published journal focused on the challenges and prospects of developing non-timber forest products in Indonesia, including bamboo [134,135]. Therefore, the result of this study described the status of bamboo's research in Indonesia for two decades. The study also discovered the topic and focus of research and the gaps that need to be conducted in the future to strengthen its development.

4. Conclusion

This study reviewed 234 papers in international journals and bamboo research and development proceedings in Indonesia. The study results revealed the current status of bamboo research and development in Indonesia for two decades (2001-2021). The analysis of published papers shows the mapping of topics and research focuses that have been widely carried out in Indonesia and illustrates trends in two decades. Research on bamboo has increased rapidly since 2014 and the aspects studied are also increasingly widespread. For two decades, research on Indonesian bamboo has mainly focused on aspects; of construction, biocomposite, and property or aspects of the utilization of bamboo and its mechanical and physical properties. However, there are still gaps in the study of bamboo Indonesia that

have not been carried out, including aspects of bamboo cultivation and aspects of strategy and regulatory support in developing integrated and sustainable bamboo utilization in Indonesia.

A well-conducted and effective literature review can provide a solid foundation for future research. Therefore an effective and good review as a research method establishes a solid foundation for advancing knowledge and identifying future research needs. The findings of this study build upon the research and efforts on the social-cultural, economic, and ecological aspects underpinnings of bamboo utilization and development. Moreover, the typology and other supporting factors that have already been carried out will bring recommendations to connect more aspects of bamboo research and fill the gaps. Furthermore, this study can be used as a reference and advice in building an integrated strategy and direction of research and development that will support the development of bamboo in Indonesia.

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