REVIEW ARTICLE

Scholarly Interest in Forest Fires in Indonesia: A Bibliographical Review

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ABSTRACT

Forest fires in Indonesia have attracted much attention among researchers over the past few decades. This paper aims to systematically map the existing corpus of scientific knowledge on forest fires in Indonesia. The systematic maps visualize which areas of significant activity and indicate specific interests and motives. The systematic analysis is also helpful in improving the understanding of current issues, problems, and challenges. From the scientific database of Scopus, we found 209 peer-reviewed journal articles directly related to forest fires in Indonesia published between 1989 and 2021 (July). In general, the number of publications rose after major fire events, notably in 1997/1998. The El Nino Southern Oscillation (ENSO)-related big fires seem to be the primary driver of more scientific inquiries. The present review shows that although fires occurred throughout the year, they mainly occurred in the dry season, indicating the crucial role of weather even though it is not the direct cause of fire ignition. Our research shows that all types of forest functions in Indonesia have experienced fires, but approximately half of the studied fires occurred in conservation areas. More specifically, previous studies have been more dedicated to secondary forests. The studies generally pointed out that secondary forests are more prone to fires. More than a half of the existing scientific work was looking at human-induced fires, although natural hazards drove that came close. Regarding human-induced drivers, most research was dedicated to the links between fires and the use of fires in land preparation for both small-scale agricultural activities and commercial plantations. The impacts of forest fires have been the most studied topic among scholars on fires in Indonesia. More specifically, the existing research was focused on the ecological/ environmental effects dominated by studies on the impacts of air quality and biodiversity. Interestingly, the existing research rarely addressed other issues, such as local livelihoods and how they adapt to environmental changes.

KEYWORDS

forest fires; direct causes; fire characteristics; fire locations; fire effects

1. INTRODUCTION

Forest fires have become a recurring disaster in Indonesia, with major fires occurring regularly. The 1982/1983 fire in East Kalimantan was reported to have burnt around 3.5 million hectares of forest (Boer, 2002). The 1997/1998 fire was also considered the worst ecological disaster, affecting 11.7 million hectares of forest area (Tacconi, 2003). Furthermore, during the more recent fire between 2014 and 2015, approximately 2.6 million hectares of Indonesia's forests were burned at various scales (Trinirmalaningrum et al., 2015). This has caught the interest of scientific communities, owing primarily to the perceived negative ecological and financial consequences. The adverse impacts are also felt at the domestic and international levels since fires in Indonesia have often led to transboundary haze problems (Aiken, 2004; Bellard et al., 2012; Parmesan, 2006; Tacconi, 2016). Recent scientific interest in forest and land fires

is also linked to climate change and its mitigation and adaptation actions (Alisjahbana & Busch, 2017; Edwards et al., 2020).

Over the past few decades, there has been growing attention on the linkages between scientific inquiries and policymaking processes. Science generated from systematic and careful procedures is often considered necessary for formulating strategies and making decisions regarding specific societal problems and challenges (Dunn, 1994; Ekayani et al., 2015; Head, 2015). Indeed, science rarely provides perfect evidence or policy solutions, but it can help provide necessary information for making decisions. However, there are gaps between science and policymaking processes. Science is often overlooked in policy processes (Nurprabowo et al., 2021). It is not utilized for its quality and objectivity but rather for considerations that do not fit the policy priorities of policymakers (Böcher & Krott, 2016; Werland, 2009). In other cases, policymakers might utilize science only for the political justification of their decisions (Spilsbury & Kaimowitz, 2000). It is also a scientific problem that does not directly relate to current practical problems and is not easily applicable. To some extent, so-called 'pure scientists' (Pielke, 2007) have little interest in influencing policy processes, and scientific exploration might be conducted for the sake of science itself (Kartodihardjo, 2013). As such, the body of knowledge generated from scientific inquiries may not provide proper solutions for the current pressing societal challenges.

This paper aims to systematically map the existing corpus of scientific knowledge on forest land fires in Indonesia. Our work has a twofold bearing. First, the systematic maps can visualize which areas of significant activity and indicate specific interests and motives (Chen, 2013). For science development, the maps are also helpful in showing potential niches for future studies. Second, a systematic bibliometric analysis may also be useful for helping improve understanding of current issues, problems, and challenges (Roberts et al., 1984). This fits with making sense of science to improve the confidence in science for policy processes (Böcher & Krott, 2016). Better understanding issues such as fire characteristics, the driving factors, and the impacts can be valuable for identifying policy alternatives and solutions.

2. MATERIALS AND METHODS

We first collected peer-reviewed journal articles on forest fires in Indonesia from the Scopus database. Scopus was selected as it provides a more comprehensive database of academic sources with greater global coverage than Web of Science and excludes gray literature that is usually covered by Google Scholar (Kulkarni, Aziz, et al., 2009). We used an advanced search with keywords (TITLE-ABS-KEY ("forest fire") AND TITLE-ABS-KEY (Indonesia)) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "EARTH") OR LIMIT-TO (SUBJAREA, "AGRI") OR LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "ENER") OR LIMIT-TO (SUBJAREA, "MULT") AND (LIMIT-TO (SRCTYPE, "j")). We collected 287 peer-reviewed journal articles published between 1989 and 2021 (July).

From the titles and abstracts, we checked whether the collected articles were related to forest fires in Indonesia. Thirty-six articles were excluded as they do not relate to fires, while another 29 articles are about fires in other countries. Another four articles were further excluded from the analysis because they were written in non-English languages. We also ensured only to use peer-reviewed articles; nine more articles were excluded as they are either reports or reviews or gray literature. Overall, we collected 209 articles for review and content analysis.

3. THE SCHOLARLY WORK: A GENERAL OVERVIEW

The studied articles were published in 136 journals, mostly related to natural sciences (78%, such as environmental science, agriculture, biology, and Earth and planetary sciences. Only a few articles were published in social science (8%) and interdisciplinary journals (14%). The existing literature indicates that forest fires in Indonesia have become a concern of global scientific communities. Based on our search, forest fires have been studied by researchers from more than 30 countries, with approximately two-thirds of the main authors affiliated with non-Indonesian institutions.

The El Nino Southern Oscillation (ENSO)-related big fires seem to be the primary driver of more scientific inquiries. In general, forest fires in Indonesia have become a significant research focus following the 1997-98 forest fires. Indonesia experienced a strong ENSO in those years, causing a longer dry season (Alsepan & Minobe, 2020). The impact of the fires which occurred during these periods was also enormous and felt in many parts of the world. Nearly a third of the analyzed articles were published during the period (**Figure. 1**). The number of peer-reviewed journals has since fluctuated; however, it remained high compared to that of the prior 1990s.

Figure 1. Trends of publication on forest fires in Indonesia

The research locations generally correspond to the occurrences of the big fires. Kalimantan and Sumatra were the most studied islands (90%), with Central Kalimantan and Riau being the notable provinces (**Figure. 2**). Only a small portion of the research was conducted in Java, Sulawesi, and Papua. Furthermore, more than three-quarters of the scientific investigations used quantitative approaches, such as satellite images or remote sensing. More specifically, they used the Fire Information for Resource Management System, derived from observations of NASA's Moderate Resolution Imaging Spectroradiometer satellite.

Figure 2. Locations of research of forest fires in Indonesia (in %)

The effects of forest fires on the environment, such as soil, air, water, and forest biodiversity, rank first on the list of all topics studied (**Figure. 3**). Nearly 50% of the

journal articles focused on the topic. Another 14% of the articles were also related to this topic, although they focused on testing methods, applications, and tools to mitigate and investigate the impact of forest fires. The high proportions of scientific publications on the topic related to fire effects are consistent over time. Despite the importance of future fire management topics such as prevention and mitigation, the characteristics, causes, and extent of fires were studied less (approximately 25%). More specifically, the limited study on the cause of fire mostly pointed to anthropogenic activities. The remaining scholarly inquiries on forest fires in Indonesia were focused on firing prevention, fire control programs, and policies.

Aggregate   Decadal trends
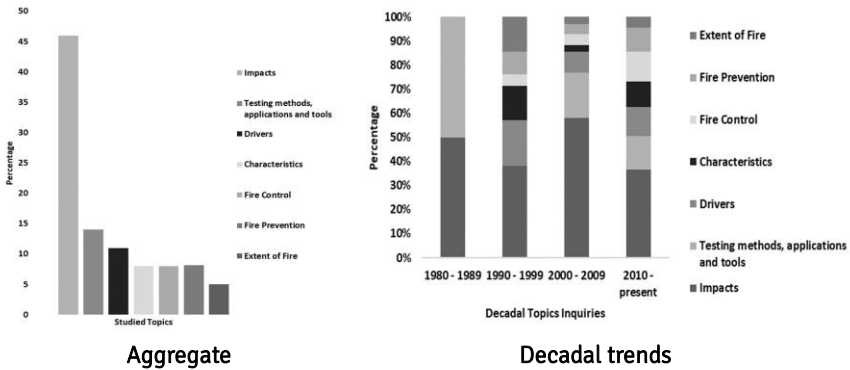
Figure 3. Studied topics and their trends of scholarly inquiries on forest fires in Indonesia

4. WHERE HAS SCIENTIFIC WORK BEEN DEDICATED TO?

4.1 Fire characteristic and location

Our review shows that although fires occurred throughout the year, they mostly occurred in the dry season (78%), peaking around September and October (**Figure. 4**), and generally declined afterward in the wet season. This indicates the crucial role of weather in the occurrence of fires, even though it is not the direct cause of fire ignition. A deep dive into the literature on fires in wet seasons confirms that they were strongly linked to the aforementioned ENSO-related weather anomalies. Although ENSO usually occurs in May–November, which coincides with the dry season in Indonesia, during the last two decades, the intensity and frequency have increased (Trenberth & Hoar, 1997). This had also impacted Indonesia's climate, most notably in 1998, when fires occurred during the wet season (February–April).
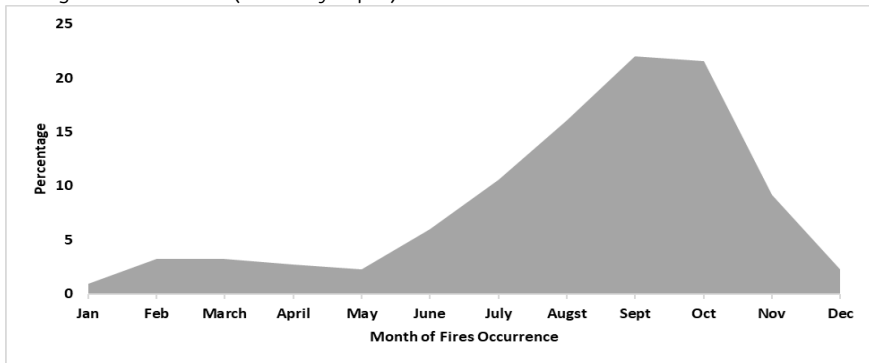

Figure 4. Occurrence of fire across the year (%)

Research shows that all types of forest functions in Indonesia have experienced with fires but approximately a half of the studied fires occurred in conservation areas (**Figure 5**). More specifically studies have been more dedicated to secondary forests. Nearly two-thirds of the studied fires took place in the forest type. The studies in general pointed out that secondary forests are more prone to fires. Our further analysis shows that a large proportion of fire research was conducted in locations close to concession areas. This links with the growing interest on the anthropogenic activities driving the fires with large scale operations were often touted as a major cause. For instance, the use of fires for land clearing to establish plantations contributed to large-scale fires. Fires in peatlands appear to draw more interest for scholarly inquiries with more than two thirds of fire research conducted in the soil type. This might relate to the growing knowledge that peatlands store more carbon than any other terrestrial ecosystems.

Forest function   Forest formation
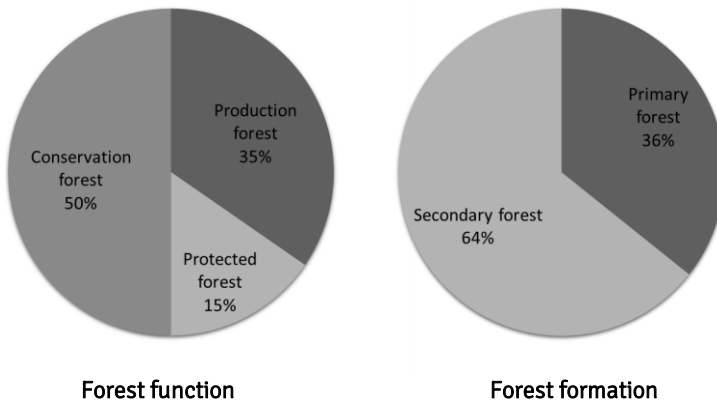
Figure 5. Research conducted in different types of forest burned (%)

Indonesia has the largest area of tropical peatlands in the world and the fourth largest extent of peatland overall, spreading across Kalimantan, Sumatra, and Papua (Page et al., 2011). Disturbance in peatlands is considered to cause severe environmental impacts (Nurhayati et al., 2021), potentially releasing the stored carbon into the atmosphere. For over 30–40 years, the forest area with this type of peat soil has significantly decreased, being converted into tree plantations (Miettinen et al., 2012). Despite this, our further probe on the existing fire research in peatland shows that most of them were not specifically aimed at assessing the carbon releases.

4.2 Drivers of fires

As mentioned in the section **4.1.,** there has been increasing interest in looking at the anthropogenic than the natural drivers of fires. Apparently, this is linked to human-induced fires being more avoidable in terms of fire management than natural disasters (Wu et al., 2021). Our bibliographic analysis supports this. More than half of the existing scientific work focused on man-made fires, though natural disasters came close (**Table 1**).

Table 1. Number of research dedicated on drivers of fires

Types of Drivers		Number of articles (%)
Natural	Weather anomaly (e.g., ENSO)	81
	Drought	15
	Animal induced	2
	Coals	2
Anthropogenic	Clearing for commercial plantation operations	26

Types of Drivers	Number of articles (%)
Clearing for small-scale agriculture expansion (slash and burn)	34
Logging and forest extraction activities	16
Infrastructure development	6
Hunting & Grazing	3
Forest cover change and deforestation	3
Others	13

Regarding human-induced drivers, most research was dedicated to the links between fires and the use of fires in land preparation for small-scale agricultural activities and commercial plantations. In Indonesia, the use of fire is a common feature in agricultural practices (Murdiyarso & Adiningsih, 2007). Commercial plantation operations are often said to be more responsible for occurring fires in Indonesia (Marlier et al., 2015), although fires driven by small-scale clearing are also significant (Purnomo et al., 2019). Our research did not aim to contribute to this debate but instead to map the existing research. We found a surprising finding that the research assessing fires caused by small-scale agricultural expansions outnumbers that of clearing for plantation operations. We further identified research on other anthropogenic drivers that includes logging activities, infrastructure development, and hunting and grazing.

Regarding nature-driven fires, most research focused on weather anomalies that lead to the reduction of rainfall during the dry season. This links to the fact that the existing research was very much motivated by ENSO (see Section **3.**). Other natural hazards include coal fires, deforestation, and wildlife-borne fires but studies dedicated on this is clearly limited. The studied articles also mentioned indirect/underlying causes of fires in Indonesia. They referred to inappropriate land management approaches, weak law enforcement, poor land-use policy & governance, and conflicts as contributing factors to fire.

4.3   Impacts of fires

As mentioned in the general overview, the impacts of forest fire have been the most studied topic among scholars on fires in Indonesia. More specifically, the existing research was focused on the ecological/ environmental effects dominated by studies on the impacts of air quality (including the links between carbon release with the rising Earth's temperature) and biodiversity (**Figure 6**).
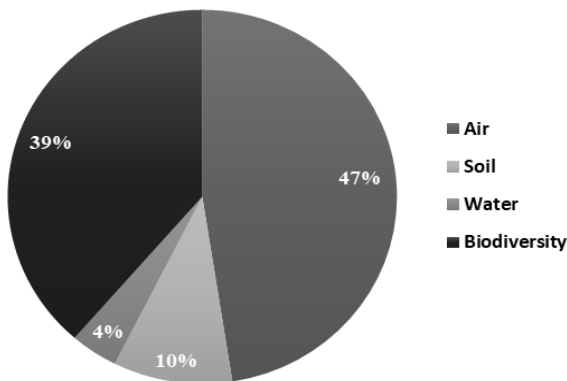

Figure 6. Extent of research on the impacts of fires (%)

Many of the impacts on air quality analyzed the composition of the gasses with carbon dioxide concentration as the core focus. This relates to climate change issues,

i.e., the increase in average the Earth's temperature. Scientific literature (e.g., Yin et al., 2018) also links an increase in temperature with the accumulation of rising CO_2 concentration in the atmosphere, including fire.

Research on the impact on the biodiversity of flora and fauna revolved around changes in abundance, composition, and richness at the studied sites. Most studies show that fires reduce plant and animal densities and alter their genetic composition, although they rarely affect the richness of surviving species. The results also show that forest loss or forest area reduction is strongly associated with fire events, whether observed from time to time using satellite imagery or based on sample plots indicated by the presence of burn scars and hotspots.

5. DISCUSSION AND CONCLUSIONS

A systematic review of the current state of research on a specific topic has a high value in scientific development. It helps identify areas of prior scholarship and supports identifying specific research questions and potential areas for future scientific priorities (Knopf, 2006; Rowley & Slack, 2004). This paper reviewed the existing knowledge on forest fires in Indonesia. Our review shows the increasing interest from domestic and international researchers in forest fires in Indonesia. The number of studies on forest fires in Indonesia significantly spiked following the event of big fires that destroyed a vast area of forests.

The 1997/1998 ENSO-driven fire in Sumatra and Kalimantan was the most studied. In general, climatic factors significantly affect the occurrence of fires (Brasika, 2022; Hidayati et al., 2020). ENSO-related fires have encouraged more scientific inquiries in Indonesia and other tropical countries (Alencar et al., 2006; Juárez-Orozco et al., 2017). Forest fires in Indonesia have continued to draw scientific interest over the past two decades, along with studies related to mitigation of climate change, i.e., the prevention of deforestation and degradation (Nurhidayah et al., 2017; Mursyid et al., 2021). In context, more than a third of the entire country's emissions between 2000–2010 were sourced from fires that occurred in concession areas (Busch et al., 2015).

We also found that more than half of the existing studies were carried out in conservation forests/areas. This could be related to a growing research interest in the value of forest biodiversity and how fire events have harmed it. This is significant because fire is common in production forests, specifically logging concessions and timber plantations (Tacconi, 2003). Logging activities increase fire risks with the increased flammability due to the canopy opening, debris, and a drier micro-climate (Herawati & Santoso, 2011). The highest fire intensity was found in the production forests (Albar et al., 2018).

Our review further mapped issues and focal topics of high interest. Interests in specific topics can be influenced by the discourses and perception of the nature of the problems and what is crucial for the society to address them (Howlett & Ramesh, 1993; Krott, 2005). We found that the existing knowledge on forest fires in Indonesia is centred around obtaining a better understanding of fire phenomena, e.g., its drivers and adverse impacts. Human activities, specifically large-scale clearing by concessions and small-scale shifting cultivation, were most studied. The high interest in studying human-induced fires is consistent with the growing perceptions of public (including mass media) on intentional burning (Ekayani et al., 2015).

Regarding the impacts, we found that the current research still focuses on adverse environmental effects, with particular interest placed on their link with climate change issues and biodiversity. In fact, those two issues were high in the global environmental discourses and policy processes (Neil Adger et al., 2001). Interestingly, the existing research rarely touched upon other issues such as local livelihoods and how they adapt

to environmental changes. This does not necessarily mean that fires did not impact other aspects. In fact, local people are most vulnerable to forest cover changes as they usually depend on the forest for their daily livelihoods (Bong et al., 2016). Law enforcement is also another interesting research area (Tacconi et al., 2019). Furthermore, the critical topics of fire prevention, fire control programs, and policies are rarely studied. Thus, this could be a promising area for future research.

To summarize, fire research may play an important role in uncovering new knowledge required for problem solving and decision making. The present research found that motivation for selecting topics and focal issues often resonate with the interests and perception of the public on what constitutes the most critical issues and problems to be addressed. This review can help policymakers understand the real problem of fires before prioritizing policy actions and approaches.

Author Contributions: **EW**: Methodology, Data collection, Analysis, Writing (draft preparation) **DM**: Conceptualization, Methodology **DHS**: Conceptualization, Methodology **AM**: Conceptualization, Methodology, Analysis, Writing (draft preparation, reviewing, editing)

Competing Interests: Authors declare no conflict of interest.

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