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Evolutionary dynamics of selective logging in the tropics: A systematic review of impact studies and their effectiveness in sustainable forest management

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ABSTRACT

Selective logging is the dominant timber harvesting practice in natural tropical forests. Considering its scale and its contribution to forest management outcome, efficient management of selective logging is crucial to address challenges associated with timber demand, carbon sequestration and biodiversity conservation. Ongoing selective logging has been a key reason for forest degradation despite a set of recommended practices such as reduced-impact logging. With the objective of drawing the attention of scholars and policy makers to answer the question why effectiveness of selective logging practice is still an issue, we tracked the trend and pattern of scholarly research related to the impact of selective logging. Using a systematic review of literature, we explored and discussed the possible factors hindering implementation of improved forest harvesting practices and the overall knowledge gaps yet not explored in this field of research. This review found consensus among scholars that implementation of improved forest harvesting is still rare despite the constant efforts made by researchers since the 1970s. Based on the review findings we concluded that concentration of research on specific countries, insufficient coverage of diversified forest dimensions/thematic areas, and higher concerns relating to ecological impacts of forest management are the reasons behind poor adoption of research outcomes of improved logging practices. Likewise, their implementation is further hindered by limited attention to the interests and needs of the forest managers/owners, lack of coordination and collaboration among stakeholders and negligible support to develop stakeholders' capacity. Our review suggests a broadening of the geographical and thematic focus of the study as well as a consideration of effective engagement and capacity development of the forest managers/owners and stakeholders in selective logging policies and practices.

1. Introduction

Selective logging is one of the most common timber harvesting practices in natural tropical forests worldwide. This is the process of extracting selected commercial trees from natural production forests (Osazuwa-Peters et al., 2015). As one of the systems to manage tropical moist forests, selective logging was first promoted in the forests of Malaysia, India, Burma and the West Africa during the period of the British and French colonial systems (Puettmann et al., 2015). Despite being a widely adopted practice since the 1950s, discussions on concerns and effectiveness of selective tree harvesting techniques as a system was started in the 1970s (Schwab and Pulkki, 2001). Currently, more than 400 million ha, about 10% of global forests, are subject to selective logging practices (Blaser et al., 2011; Edwards et al., 2014; Martin et al., 2015). These natural tropical forests are crucial for providing multiple ecosystem services of greater ecological and economic importance (Edwards et al., 2014; Bicknell et al., 2015). For instance, selective logging alone contributes nearly 15 percent of the global timber supply (Martin et al., 2015). Although people remove only the commercially valuable trees under this approach, there are increasing concerns about the contribution of these practices to forest degradation (Shearman et al., 2012; Brandt et al., 2016; Griscom et al., 2017). Therefore, assessment of selective logging is crucial to respond global timber demand and to reduce forest degradation.

Selective logging practices determine the outcome of sustainable forest management (SFM). SFM is the process of managing a forest to achieve specified objectives of management, ensuring a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity (ITTO., 2016). Improved forest harvesting practices play a crucial role in ensuring a continuous

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flow of forest goods and services and therefore are necessary in meeting SFM objectives (Palmer and Synnott, 1992). However, evidence of SFM is rare (Putz et al., 2008). The International Tropical Timber Organisation (ITTO) estimates that less than 10% of the total permanent forest estate of tropical countries is managed sustainably (Blaser et al., 2011) indicating the rationale of effective logging practices.

As a dominant forest harvesting practice, effective management of selective logging could address a number of challenges associated with increasing demand for wood products (d'Annunzio et al., 2015), while avoiding the increase in carbon emissions from tropical forests (Köhl et al., 2015; Pearson et al., 2017) and decreasing the trend of terrestrial biodiversity loss (Leadley et al., 2014). However, actual selective logging practices have contributed to forest degradation, leading to decreased product supply (Irland, 2011), decreased carbon stock potential (Pearson et al., 2014), and decreased quality of wildlife habitat (Martin et al., 2015). Of the total forest degradation related emissions from tropical countries, 53 percent is due to ongoing selective logging practices (Pearson et al., 2017). Because of this fact, ongoing selective logging has not been able to meet the multi-functional objectives of SFM and therefore it is critical to assess those practices to make future endeavours more efficient and sustainable (Keith et al., 2015).

Given the increasing realisation of the need for balanced ecosystem services from natural forests, improved forest harvesting techniques known as reduced-impact logging (RIL) were promoted from the early 1980s (Schwab and Pulkki, 2001). The primary objectives of RIL were to improve efficiency in forest harvesting and minimize the environmental and social impact of selective logging (Applegate et al., 2004). The implementation of RIL has, however, been too sporadic and largely limited to use for site-specific research purpose (Putz and Romero, 2015). One of the reasons behind is uncertainty on the benefits of RIL to harvesters over conventional logging (Medjibe and Putz, 2012). Further, there are negligible studies on trade-offs of adopting better silvicultural practices (Putz and Romero, 2015). Existing studies on selective logging lack the clear and consistent message to policy makers and harvesters due to inconsistency in measurement variables and different interpretation (Medjibe and Putz, 2012). Moreover, knowledge of the factors influencing effective and wider application of improved selective logging practices is lacking.

The main purpose of this review is to identify the knowledge gaps in selective logging practices. Therefore, exploration of the evolutionary dynamics of selective logging is crucial to portray the mechanisation and development process of natural forest harvesting in the tropics. Our review has tracked the trend and pattern of studies related to the impact of selective logging practices with the aim of offering insights into planning forest management activities in the future. In addition, we have also identified the possible reasons behind such trends and have linked them with the global environment and with forest related policy discourses. Highlighting the trend of such studies, we intend to draw the attention of scholars and policy makers to the question of why effectiveness of improved forest harvesting practices remains an issue for SFM (Puettmann et al., 2015). While doing so, we have explored and discussed the possible factors hindering both the implementation and the overall knowledge gaps not yet investigated in this area. A number of forest harvesting practices such as RIL (Putz et al., 2008), retention forestry (Lindenmayer et al., 2012), close to nature forestry (O'Hara, 2016), and silvicultural intensification (Putz, 2015) have been adopted in natural tropical forests in the last four decades. However, our key focus remains the studies that have discussed the impacts of RIL on timber production, carbon sequestration and plant species richness, because RIL is considered as a key intervention in selective logging (Putz et al., 2008; Vidal et al., 2016).

The first section introduces the problem and highlights the aims and rationale of exploring selective logging. The second section expands on the methods used to develop the review, while section three presents key findings of the review. The fourth section discusses the possible causes and implications of the findings. Finally, the conclusion section presents the key message to consider, based on the review findings and discussions.

2. Review framework and methodology

Our study is primarily based on the review of literature on selective logging and its impacts. In general, our review focused on the evidence of effectiveness and the issues around selective logging practices. Specifically, we followed the systematic review guidelines suggested by Pullin and Stewart (2006) because of their specific focus on conservation and environment management. This review aims to answer the question: what is the trend and pattern of impact studies in selective logging in terms of thematic focus, geographical coverage and temporal growth? We searched the peer-reviewed articles published between 1996 and 2017 in the web-based databases *"Scopus"*, *"Web of Science"* and *"Science Direct"*. We used the key terms ("Selective Logging" OR "Selective Harvesting" OR "Reduced Impact Logging" OR "Crown Thinning" OR "Selective Cutting") AND ("Timber Production" OR "Carbon" OR "Tree Species Richness" OR "Biodiversity") AND "Tropical Forests" in title, abstracts and the key words choosing "ALL" category in the search. These terminologies are widely used in the literature to deal with harvesting practices of uneven aged tropical natural forest (see Fig. 1).

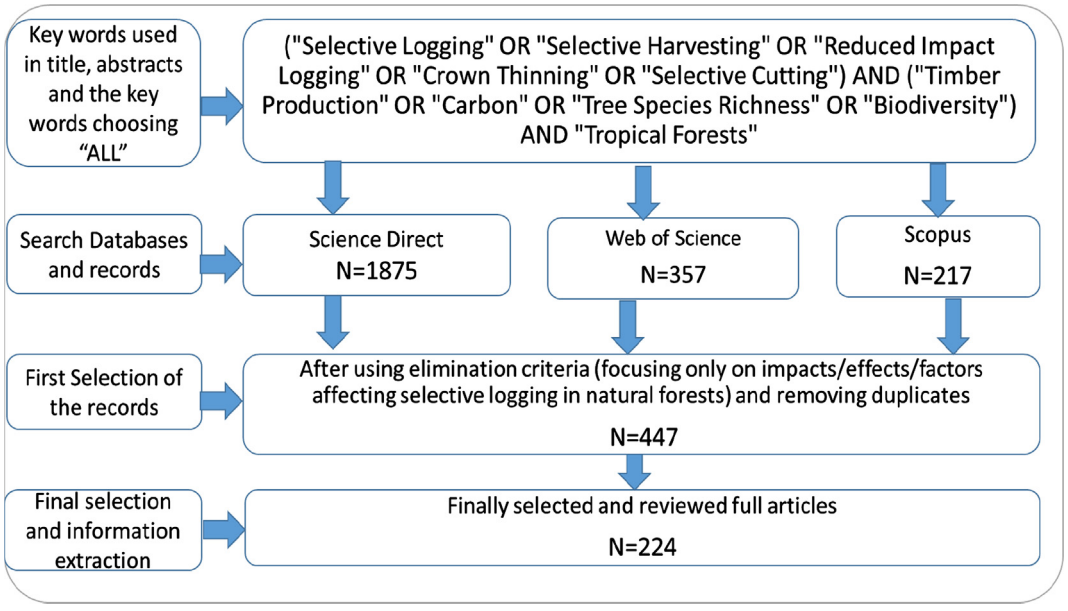

Fig. 1. Criteria and procedure of literature search for systematic review. *N = Total number of articles.