

Review Paper

Unveiling economic dimensions of peatland restoration in Indonesia: A systematic literature review

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ABSTRACT

Indonesian peatlands play a critical role in global carbon storage and biodiversity conservation, but they face significant ongoing threat of degradation and loss due to human-induced pressures, including the development of industrial plantations, agricultural expansion, extractive forestry practices, and recurrent fires. The imperative to restore these peatlands is significant, but the restoration effort has, so far, been underwhelming. This paper systematically reviews studies that have assessed the economic costs and benefits of peatland restoration in Indonesia. It summarizes the substantial economic stakes involved in peatland restoration efforts, ranging from millions to billions of dollars. The collective findings emphasize the significant costs required for restoration, alongside the potential economic benefits derived from environmental conservation, climate change mitigation, and sustainable land management. These economic valuations are complemented by a holistic consideration of ecological, social, and cultural factors, providing valuable insights for policymakers and decision-makers. However, while these studies have offered valuable insights into various aspects such as local preferences, willingness to pay, financial costs, and potential economic benefits, none have comprehensively explored the potential trade-offs or forgone opportunities resulting from the proposed restoration programs. This is a critical gap in current research and practice. We illustrate the need for more systemic learning about how peatlands are valued to advance a transition towards healthier peatlands in Indonesia.

1. Introduction

Around 30 % of global tropical peatlands are located in Indonesia, mostly on Sumatra (43 % of Indonesian peatland area) and Kalimantan (32 %); the next largest area is in Papua (25 %) (World Bank, 2018; Anda et al., 2021). Together with coastal swamplands and mineral soils they form Indonesia's lowlands which are the source of considerable economic benefit for Indonesia, mainly from production of food and industrial crops (World Bank, 2020), energy, construction materials, bedding for livestock and medicinal needs (Clarkey & Jack, 2010). Historically, local populations have obtained a range of products from peat swamp forests, including timber to build housing, food, latex, fibre, medicinal and household materials for their survival (Warren et al., 2017). Peatlands also provide a wide range of ecosystem services (ES)

that include protection of water resources (Surahman et al., 2017; Joosten et al., 2012), terrestrial carbon storage (Peacock et al., 2013); Quin et al., 2014), recreation and biodiversity (Surahman et al., 2017; D'Astous et al., 2013), and mitigation of soil erosion (Wilson et al., 2011). Due to loss of many lowland forests on mineral soils, peat swamp forests have also become an important habitat for endangered iconic species such as the orangutan, the Sumatran elephant, and the Sumatran tiger (International Agricultural Centre, 2004; Morrogh-Bernard et al., 2003; Rendana et al., 2023; Rieley, 2016).

Despite their considerable environmental significance, only 6 % of Indonesian peatlands remain intact while 13.4–14.9 million ha (87–97 %) are considered degraded (Yuwati et al., 2021). Lestari et al. (2023) estimated that 6 million ha, or approximately 45 % of Indonesia's peatland area, could potentially be restored. Degradation of peatlands

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occurs mainly due to anthropogenic drivers such as forest logging, industrial plantation development, agricultural expansion, and recurrent fires (Dohong et al., 2017; Miettinen et al., 2016; World Bank, 2020). Degradation intensifies peat decomposition rates (Hirano et al., 2014), heightens susceptibility to wildfire (Edwards et al., 2020; Leng et al., 2019), and is the source of 30–60 % of Indonesia's annual greenhouse gas (GHG) emissions (Langston et al., 2024). Accentuated by climate change, degradation changes peatlands from being a net greenhouse gas sink to a net source (Frolking et al., 2011) and further threatens the provision of the critical services they provide (Glenk et al., 2014). Beyond adverse climate implications, peatland degradation and associated fires are significant source of air pollution, adversely affecting human health (Betha et al., 2014; Uda et al., 2020), exacerbating biodiversity loss (Syaufina & Abi Hamzah, 2021), and inflicting additional economic losses (Glauber et al., 2016; Kiely et al., 2021). Thus, despite playing a crucial role in global carbon storage and biodiversity conservation, peatlands in Indonesia face considerable threats, particularly from degradation due to human activities (Girkin et al., 2022).

Widespread acknowledgement of the cumulative and negative effects of many prior and ongoing practices has led to an extensive and expanding body of literature emphasizing the imperative for sustainable peatland management. This literature underscores the importance of restoring degraded peatlands and prioritizing the protection of those that still maintain their pristine condition (Dhandapani et al., 2020; Evers et al., 2017; Wijedasa et al., 2017). An increasing number of field investigations have systematically assessed the ecological repercussions of peatland restoration initiatives, impacts of climate change, seeking to understand their impact on vital ecological functions encompassing carbon sequestration, collaborative approaches, community perception of restoration activities, and inevitable challenges in the process of peatland restoration and conservation in Indonesia (Fleming et al., 2024; Jalilov et al., 2024; Kunarso et al., 2024; Mendham et al., 2024; Sakuntaladewi et al., 2024; Toumbourou et al., 2024).

Interest in ES and their economic valuation has grown substantially over the past two decades (Wichmann et al., 2016). Significant policy-oriented efforts include the Millennium Ecosystem Assessment (MA, 2005) and the Economics of Ecosystems and Biodiversity (TEEB, 2010). Indonesia has been a member of the Wealth Accounting and Valuation of Ecosystem Services (WAVES) since 2013 (formalized in 2015) and aims to integrate natural capital accounting into its medium-term development plan, highlighting the link between conservation and wellbeing. Peatland restoration is of critical importance, and there remains a need to comprehensively assess the economic costs and benefits associated with restoration. The extensive economic valuation literature on wetlands contrasts sharply with the paucity of studies assessing the value of peatland ES. This is exacerbated by the lack of standardization in results across various studies, which hinders meaningful comparisons (Wichmann et al., 2016). As peatlands provide distinct services and face unique restoration costs, advancing standardized valuation approaches would enable more consistent, comparable, and actionable insights for policy and investment.

A quantitative consolidation of peatland restoration outcomes in Indonesia is timely and needed to provide valuable insights into prevalent research patterns and gaps. Such a synthesis could be useful for institutions and investment strategies that shape policies and interventions that affect peatlands. Although existing literature provides frameworks and typology for classifying, describing, and valuing ES, thematic and case-based reviews (e.g., on global regions (de Groot et al., 2002; Glenk & Martin-Ortega, 2018), carbon storage and land use impacts (Glenk & Martin-Ortega, 2018; Goldammer, 2006; Hergoualc'h & Verhot, 2011; Leifeld & Menichetti, 2018; Page & Hooijer, 2016), there is a critical gap in the economic literature on peatland restoration in Indonesia, specifically in the monetary valuation of restoration costs and benefits. Quantitative valuation of both costs and benefits is needed to inform targeted conservation policies and financial strategies.

2. Aims and scope of the systematic review

As part of an interdisciplinary team developing a roadmap for the restoration of Indonesia's peatlands (<https://gambutkita.org/>), our study seeks to undertake a systematic assessment of the monetized costs and benefits of peatland restoration in Indonesia as reported in the peer reviewed literature. This systematic literature review aims to answer the question: *“What is the evidence regarding the economic costs and benefits of various peatland restoration methods in Indonesia, and how do they compare?”* A systematic literature review of the economic costs and benefits of various peatland restoration methods in Indonesia aims to synthesize existing research, assess the economic implications, and provide a comprehensive analysis of the economic aspects related to peatland restoration in the country.

As such the review aims to achieve several key objectives. Firstly, it seeks to comprehensively characterize the existing body of literature on the economic costs and benefits associated with various peatland restoration methods in Indonesia. This involves an in-depth investigation into the values studied, the methodologies used, geographical variations, and the aspects of ecosystems considered in the reviewed studies. Secondly, it aims to critically examine and assess the limitations inherent in conventional economic assessments of peatland restoration, identifying challenges and potential areas for improvement in existing literature. Furthermore, the review endeavours to contribute to the advancement of best practices in the field of peatland restoration economics.

The selection criteria for the economic analysis were designed to ensure a comprehensive and rigorous assessment of ES valuation studies. Specifically, we focused on studies that explicitly quantified the monetary value of ES and provided transparent information about the valuation methods employed. This approach was chosen to prioritize studies that offer robust and quantifiable insights into the economic contributions of ecosystems. While we acknowledge that ES encompass a wide range of benefits and costs, including those that may be challenging to monetize, our objective in this analysis was to focus on studies that provide quantifiable monetary estimates. This decision was driven by the need for comparability and consistency within the economic framework, allowing for a more rigorous evaluation of ecosystem service values across different contexts and regions. It's worth noting that while our analysis primarily focuses on monetary valuation, we recognize the importance of qualitative dimensions and non-monetary values associated with ES. In cases where studies consider qualitative dimensions alongside monetary valuation, we aim to provide a nuanced interpretation of the findings to capture the broader implications for ecosystem management and policy decisions. By adhering to transparent selection criteria and focusing on studies that explicitly quantify monetary values, we aim to provide a robust and evidence-based analysis of ecosystem service valuation while acknowledging the broader complexities and nuances inherent in ecosystem management and decision-making.

3. Protocol for systematic literature review

We systematically searched the peer-reviewed literature to identify quantitative studies about the economic costs and benefits of peatland restoration in Indonesia. Articles were identified through ISI Web of Science Core Collection, JSTOR, Scopus, JOLIS through comprehensive search outlined below. The three selection criteria below were utilized for the study.

- Criterion 1: Only the effects of active restoration (i.e., planting/revegetation, hydrological rehabilitation) were included. Passive restoration, which involves natural succession without human intervention, is considered as naturally regenerated peatland for comparison purposes and was excluded from the review.

- Criterion 2: For the economic analysis, only studies specifically mentioning the monetary value of ES and the valuation method were selected. The rationale is described in the previous section.
- Criterion 3: Finally, publications only in English language were reviewed.

The PRISMA protocol was followed for study selection and inclusion (Sarkis-Onofre et al., 2021) (Fig. 1). The search was performed using generic wording for restoration impact on 19 January 2024 with no restriction on publication year, therefore, it included all studies up to that date. The search keywords were informed by preliminary review of the literature and the authors' expert knowledge. We included the following combination of terms and Boolean operators – ("peatland restoration"), AND (benefit OR cost), ("total economic value"), ("economic valuation") AND (Indonesia) in Title, Abstract, Keywords. We

tried variations of this search text, but found alternative combinations to be less accurate, yielding thousands of studies, for which the vast majority were unrelated to our research question.

In total 134 articles were identified, of which 35 were discarded after a first screening of the title and abstract for duplication. During the second screening the full text was read to judge its suitability for inclusion. The search was limited to peer-reviewed journals and valuations from the grey literature and documents were not included. Finally, nine articles representing cases of peatland restoration met the inclusion criteria. The full list of all nine reviewed articles with their summaries and short description of methods and findings is included at the end of the [Supplementary Information \(Appendix A\)](#).

4. Framing the economics of peatland restoration

Peatland restoration endeavors involve facilitating the recovery of

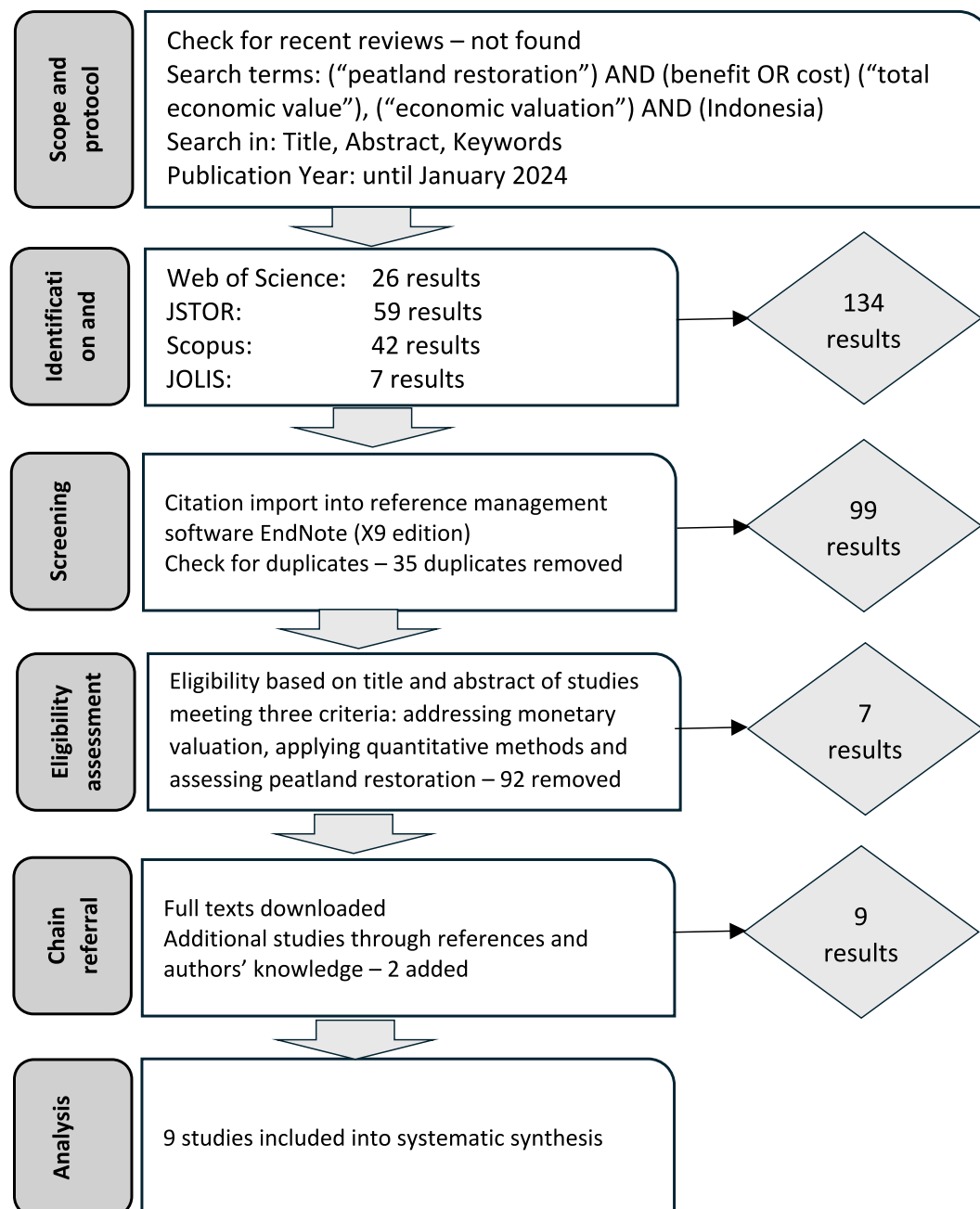


Fig. 1. PRISMA flow diagram of literature review process for studies on peatland restoration costs and benefits in Indonesia.

degraded ecosystems, potentially reinstating their original composition, structure, and function, and/or the ES provided by intact peatland. Typically, restoration initiatives operate at a site level but entail landscape-scale benefits and costs, aiming to restore ecological integrity and enhance human wellbeing in deforested or degraded peatland landscapes. Objectives vary and may include reinstating ES like hydrological balance, recreating native habitats, and/or improving livelihoods. Consequently, peatland restoration is pivotal for providing a range of economically valued ecosystem goods and services such as carbon sequestration, habitat for biodiversity, water quality improvements, and amenity value.

The costs of restoration initiatives depend on several factors, including costs associated with delivery, implementation, and maintenance, alongside the opportunity costs of alternative land use (Wilson et al., 2012). Delivery costs are influenced by the complexity of the restoration process and its ability to achieve biodiversity and ecosystem service benefits. Implementation and maintenance expenses vary by the restoration strategy employed, with passive methods potentially being more cost-effective compared to intensive planting. Additionally, different restoration approaches require varying time frames to achieve biodiversity and ecosystem service objectives.

Peatland restoration entails both direct and indirect costs (Puspitaloka et al., 2021). Direct costs encompass expenses incurred during physical implementation, such as rewetting, revegetation, monitoring, and fire prevention measures. These costs are typically quantified using market-based approaches but may not fully account for site-specific variations or community involvement. Indirect costs include opportunity costs, economic losses, relocation and compensation costs, transaction costs and institutional and capacity-building expenses. However, these estimates may not fully capture the complexities of land-use changes or market fluctuations.

The wide array of benefits flowing from peatland ecosystems is delineated through the differentiation of economic value (representing welfare), socio-cultural value (reflecting wellbeing), and ecological value (pertaining to ecosystem integrity and life-support functions) (de Groot, 2006; Wilson et al., 2012). The valuation of peatland ES integrates various disciplines, including ecology (for understanding and quantification), ethics (e.g., considerations of intergenerational justice), politics (for goal setting), as well as economics, psychology, and sociology (for elucidating underlying values and motivations) (Wilson et al., 2012).

The Total Economic Value (TEV) concept acknowledges that the economic value of a natural resource is contingent not only upon its potential as an input in production but also on other benefits it can bestow upon people. TEV distinguishes between direct or indirect use values and non-use values (Fig. 2). This distinction holds significance in selecting appropriate valuation methods (Wichmann et al., 2016). Embedded within an anthropocentric utilitarian framework, this

concept finds widespread application in economic valuation. Three methodological approaches to economic valuation can be distinguished: utilizing existing markets for the relevant goods and services (direct market valuation), inferring the value of goods and services indirectly through analyzing related markets or observing behavior (revealed preference approaches), and directly querying individuals about the value they attach to goods and services (stated preference approach) (Wilson et al., 2012).

5. Findings and discussion

Broadly, the results described below indicate that the literature on the valuation of the costs and benefits of peatland restoration in Indonesia is limited, inconsistent, and has significant caveats, presenting an opportunity for further research to establish a more consistent and robust foundation for policy recommendations. We summarize the results as follows: The first subsection offers an overview of the studies, including the initiating institutions, publication year, and geographic scope. Following this, we present the valuation methods used, the costs and benefits of peatland restoration, and the obtained values, accompanied by a detailed discussion of the results.

5.1. Overview of the reviewed studies

Nine papers have been identified as meeting the predetermined inclusion criteria for this systematic review (Fig. 3). The inception and financial support for these studies were the result of collaborative endeavours involving multiple universities (Kiely et al., 2021; Puspitaloka et al., 2021; Tarigan et al., 2021), Australian universities (Hansson & Dargusch, 2017), independent institutions in Singapore (Lin et al., 2017), and the Netherlands (Rossita et al., 2021), a spectrum of governmental bodies (Budiharta et al., 2018), including the government of Norway (Januar et al., 2023), and a consortium of non-governmental organizations (NGOs) (Schaafsma et al., 2017). The collaborative approach in these studies and Indonesia's peatland restoration efforts underscores the necessity of multidisciplinary and multi-stakeholder engagement. Addressing the complexity of peatland ecosystems requires the combined expertise, resources, and perspectives of universities, government bodies, and NGOs. This synergy enhances research, informs effective strategies, and fosters knowledge exchange, capacity building, and a shared commitment to sustainability.

1 reviewed studies were conducted between 2017 and 2023. Specifically, two studies were conducted in 2017, two in 2018, four in 2021, and one in 2023 (Fig. 3). The late emergence of valuation studies, beginning in 2017, reflects the growing policy and scientific attention to peatland restoration in Indonesia, spurred by increasing awareness of the ecological, economic, and social importance of these ecosystems. This timing aligns with heightened global and national efforts to

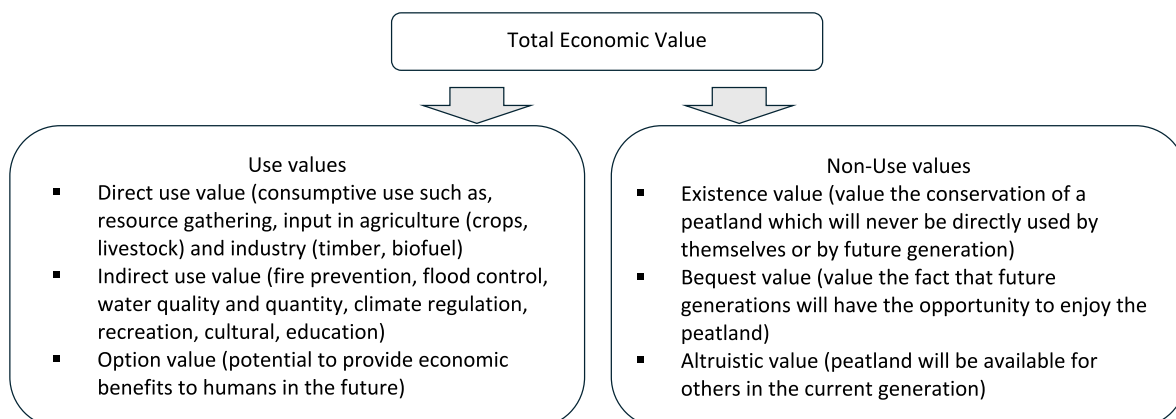


Fig. 2. Total economic value typology with examples of peatland ecosystem services.

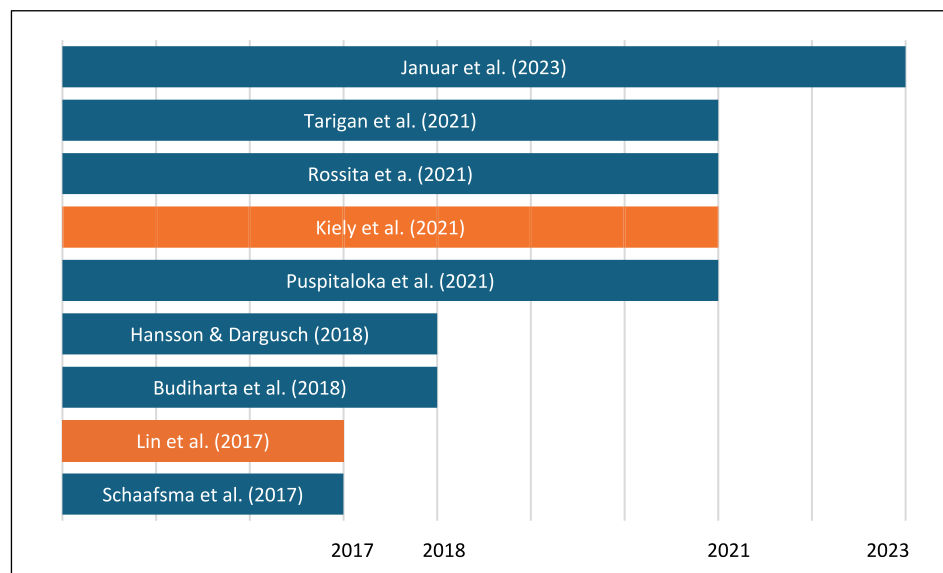


Fig. 3. Overview of reviewed studies by year and geographic coverage (orange – national, dark blue – provincial). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

mitigate the devastating impacts of peatland degradation, such as carbon emissions and biodiversity loss. Notably, this timeframe coincides with the aftermath of the devastating fires of 2015/16, which prompted the Indonesian government to establish the Badan Restorasi Gambut (BRG, or Peatland Restoration Agency), which in 2020 was subsequently expanded to include mangrove restoration, or BRGM. The establishment of the BRGM signified a substantial investment by the Government of Indonesia to enhance the prominence of peatland restoration, both domestically and internationally (Indrajaya et al., 2022). The core principles of the BRG are encapsulated in the “3 Rs” framework: Rewetting of the peat soil, Revegetation with native species, and Revitalization of livelihoods for communities engaging in unsustainable land management on peatland (Mendham et al., 2024).

The geographical focus of the published work mostly focussed on Central Kalimantan (5 studies), which has experienced some of the most severe peatland degradation in Southeast Asia (Schaafsma et al., 2017; van Beukering et al., 2008). Two of the studies extended their purview to include provinces in Sumatra and Papua (Hansson & Dargusch, 2017; Tarigan et al., 2021), covered Riau province (Rossita et al., 2021) and two covered the entire country (Kiely et al., 2021; Lin et al., 2017) (Fig. 3). Notably, the majority of these studies adopted a case study approach because, despite their relatively small geographical footprint, peatlands play a critical role in global environmental issues and present complex challenges that require in-depth analysis (Balint, 2011; Langston et al., 2024).

5.2. Methods of analysis

All considered studies aimed to inform decision-making and policy development related to peatland restoration, but their methodological approaches differed. Some studies combined monetary valuation with qualitative field estimation, providing a more comprehensive understanding of both economic and social dimensions. Others focused exclusively on monetary valuations, either estimating willingness to pay, direct costs of restoration activities, or potential economic benefits of restoration efforts. However, the specific methodologies and scopes of these valuations have varied across studies.

Some studies, such as the one by Schaafsma et al. (2017), employed a mixed-method approach that combined monetary valuation techniques with qualitative field estimation methods. The choice experiment aspect allowed for quantifying preferences and economic values related to

different attributes of peatland restoration programs, such as tree-planting, fire policies, and community involvement. This monetary valuation aspect of the study aimed to estimate the willingness of local communities to engage in restoration efforts and the compensation required for their participation. On the other hand, the focus group discussions provided qualitative insights into local perceptions, attitudes, and values related to peatland restoration. Through interactive group discussions, the researchers gathered qualitative data on community motivations, concerns, and preferences regarding restoration activities. This field qualitative approach complemented the monetary valuation by offering a deeper understanding of the social context and non-monetary aspects of peatland restoration. By combining monetary valuation techniques with field estimation methods, the study was able to provide a comprehensive assessment of the benefits and costs of peatland restoration from both economic and social perspectives, offering valuable insights for decision-making and policy development in the context of sustainable land management in Central Kalimantan (Schaafsma et al. 2017).

Other studies, like those by Lin et al. (2017) and Hansson and Dargusch (2017), focused solely on monetary valuation methods. Lin et al. (2017) used contingent valuation surveys to estimate Singaporeans' willingness to pay for mitigating transboundary haze from forest fires in Indonesia. In contrast, Hansson & Dargusch (2017) aimed to assess the financial costs of peatland restoration efforts in different Indonesian provinces.

Several studies concentrated on valuing the costs associated with peatland restoration for specific purposes. Budiharta et al. (2018) focused on monetary valuation of peatland restoration activities in the context of carbon offsetting. It estimates the costs associated with restoring degraded deep peatlands to offset carbon emissions from industrial oil-palm development in Indonesia. The valuation is based on the cost required for restoration activities, including factors such as planting, maintenance, and rehabilitation of hydrological conditions. The study uses economic analysis to assess the feasibility and implications of peatland restoration as a strategy for carbon offsetting, emphasizing the monetary aspects of restoration efforts in the context of environmental conservation and land-use practices (Budiharta et al., 2018).

Puspitaloka et al. (2021) developed an accounting framework to estimate the direct and indirect costs of restoration projects managed by different proponents in Central Kalimantan. The study aimed to provide

empirical assessments of the challenges and costs of peatland restoration projects managed by different proponents in the region. The researchers developed an accounting framework to estimate the total costs of restoration activities, including both direct and indirect costs. The study also reviewed existing policy contexts to propose governance alternatives to sustain peatland restoration efforts. While the study did not specifically mention experimental estimation of benefits, it did involve fieldwork, key informant interviews, and document analyses to gather data on restoration activities, challenges, and costs. The focus was on assessing the financial investments required for peatland restoration projects and exploring funding mechanisms to ensure the long-term sustainability of restoration efforts [Puspitaloka et al. \(2021\)](#).

Taking a broader perspective, [Kiely et al., 2021](#) conducted a monetary valuation by quantifying the economic losses from fires in Indonesia and comparing them with the potential benefits of peatland restoration in terms of reducing fire-related costs and damages. This approach highlighted the economic incentives for restoration efforts without directly estimating the costs of specific restoration activities. The analysis centred on quantifying the economic impacts of fires, including health impacts, CO₂ emissions, and damage to crops, forests, and plantations, to assess the monetary implications of peatland restoration efforts. The study did not involve field experiments or direct field estimations of benefits or costs but rather relied on economic modelling and data analysis to evaluate the financial aspects of peatland restoration [\(Kiely et al., 2021\)](#).

[Rossita et al. \(2021\)](#) utilized a combination of primary and secondary data sources in their study. Primary data for identifying the monetary value of provisioning services were collected through field visits supported by local agriculture instructors from the Ministry of Agriculture in Riau. A total of 21 respondents, mainly leaders of local Farmer Groups (Gapoktan), were involved in the data collection process. Secondary data, including statistical reports and spatial data, were obtained from various institutions such as Statistics Indonesia (BPS) and other relevant sources. The statistical reports covered agriculture and estate crop commodities from 2001 to 2017 for all nine subdistricts within the study area. Spatial data were also incorporated into the analysis using ArcMap 10.5 as the spatial analysis tool.

[Januar et al. \(2023\)](#) employed economic cost-benefit analysis to evaluate different peatland management scenarios, focusing on the Net Present Value (NPV) as a metric to assess the long-term economic implications of restoration efforts.

Finally, [Tarigan et al., \(2021\)](#) used a combination of modeling techniques and data analysis to assess the ES provided by tropical peatlands and to evaluate the economic implications of different peatland management scenarios. The study integrated multiple approaches to assess peatland restoration, combining hydrological and carbon modeling, economic valuation, and uncertainty analysis to capture ecosystem service values under varying scenarios. The Soil and Water Assessment Tool (SWAT) model assessed water resource impacts from land-use changes, while the Integrated Valuation of Ecosystem Services and Tradeoff (InVEST) model evaluated carbon storage across scenarios. NPV analysis with a 10 % discount rate was used to assess long-term economic benefits, accounting for the social cost of carbon. Additionally, uncertainty and scenario analyses compare ecosystem service benefits across different peatland management practices, enhancing the robustness of the findings.

5.3. Economic value of peatland restoration

Monetary valuation studies are gaining prominence in environmental decision-making processes, aiming to assess the efficiency of ecosystem management by measuring improvements in social welfare [\(Brewer et al., 2020\)](#). The outcomes of valuation studies play a pivotal role in appraisal tools like social (or extended) cost-benefit analysis, as well as in the formulation of policy instruments such as Payments for Environmental (or Ecosystem) Services or other pricing mechanisms.

Outcomes from these inquiries suggest that values of each system are shaped by the specific focus, contextual nuances, and methodological variances among the studies, posing challenges for broad generalizations.

[Fig. 4](#) illustrates the range of costs for peatland restoration in Indonesia as identified by the reviewed studies. This representation is somewhat arbitrary since comparing studies is challenging due to variations in the aspects of costs considered, differing levels of peatland degradation, and other factors. However, after converting local currency values into US dollars and adjusting for inflation to the year 2024 based on Consumer Price Index (CPI) data [\(Bureau of Labor Statistics, 2024\)](#), the graph provides useful information. Most of the reviewed studies report peatland restoration costs in Indonesia to be between US\$500 and US\$2,500 per ha. Detailed valuation information is provided below.

The study of [\(Schaafsma et al., 2017\)](#) focussed on estimating the direct payments that communities might be willing to accept for peatland restoration activities in Central Kalimantan. It used a choice modelling approach combined with focus group discussion to understand the compensation needed to sustain local community involvement in three restoration activities: tree planting, fire prevention, and other community engagement activities (including microcredit and extension services). The study aimed to provide arrangements that secure stable income, food supply, and create awareness of the long-term benefits of peatland restoration. While the study did not explicitly quantify indirect costs, it indirectly addressed broader economic, social, and environmental impacts associated with restoration efforts. The estimated willingness to accept (WTA) compensation levels ranged from ~US\$96/ha for tree-planting to US\$153/ha for a ban on burning in Central Kalimantan. Focus groups provided insights into local perceptions, attitudes, and non-monetary values surrounding restoration. Key benefits addressed were fire prevention by reducing peat fire risk, water pollution mitigation through improved hydrology, carbon sequestration, and provisioning of ES like timber and non-timber forest products.

The study of [\(Lin et al., 2017\)](#) examined the willingness to pay (WTP) of Singaporeans to mitigate transboundary forest-fire haze from Indonesian peat fires, with a primary focus on estimating the indirect costs of peatland restoration. Utilizing contingent valuation surveys, the study found Singapore's substantial WTP to be US\$643.5 million annually for haze mitigation, funds that could potentially be directed towards land conservation and peatland restoration initiatives. While the study did not provide a detailed breakdown of direct restoration costs, such as land preparation or reforestation, it evaluated the broader economic impact of peatland restoration in the context of haze pollution mitigation. These costs are considered indirect as they reflect the economic implications of addressing the root causes of haze pollution through restoration efforts. By estimating WTP for mitigation, the study indirectly addressed the costs associated with implementing restoration strategies to reduce peat fires and haze pollution in the region. While providing context on fire prevention and carbon sequestration benefits of restoration, the study had a narrower economic lens and lacked depth on broader environmental and social benefits. The calculated

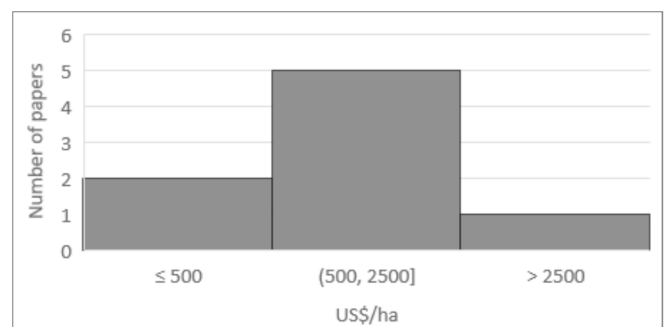


Fig. 4. Range of adjusted peatland restoration costs by reviewed papers.

comparative peatland restoration cost per ha is US\$750/ha, obtained by dividing the total WTP by 858,000 ha, the estimated area of peatlands burned in the 2015 forest fires (Lin et al., 2017). However, it is important to note that differences in income levels between Singapore and Indonesia influence WTP values, potentially limiting the direct applicability of these findings to the Indonesian context. While this study underscores the broader regional benefits of restoration efforts, its WTP estimates should be viewed as reflective of international externalities rather than as a direct measure of local Indonesian valuation.

The study conducted by (Budiharta et al., 2018) offered a comprehensive evaluation of the costs associated with peatland restoration efforts. Direct costs encompassed expenses related to planting activities, maintenance, and the restoration of hydrological conditions on degraded peatlands. These costs are determined based on the standard rates for forest rehabilitation in Indonesia, as prescribed by the Ministry of Forestry (Budiharta et al., 2018). They are further differentiated according to the restoration approach employed and the initial level of degradation. In addition to direct costs, the study also considered indirect costs, primarily in the form of opportunity costs associated with alternative land uses such as oil-palm plantations, logging, and agroforestry. By accounting for the revenues forgone from these alternative land management practices, the study provided a comprehensive assessment of the economic implications of peatland restoration efforts. The analysis covered carbon offsetting potential through rewetting and revegetation, balanced carbon sequestration goals with biodiversity conservation, fire prevention by mitigating peat fire risks, water pollution reduction by preserving hydrological functions, as well as socio-economic impacts like community involvement, job creation, and sustainable livelihoods. Specifically, (Budiharta et al., 2018) estimated the cost of restoring degraded deep peatlands for carbon offsetting purposes within the context of industrial oil-palm development in Kalimantan. At an estimated restoration cost of US\$1625/ha, their analysis projected a wide-ranging cost estimate of US\$0.4 to US\$2.9 billion for fully offsetting oil-palm derived emissions through restoration activities (Budiharta et al., 2018).

The study by (Hansson & Dargusch, 2017) estimated the direct costs of restoration activities in Indonesia. The researchers focused on calculating the financial expenses associated with restoration efforts, such as hydrological restoration of canals, revegetation, and other specific activities required to restore degraded peatlands. With indirect or opportunity costs not accounted for, the estimated average lowest cost was US\$1,866/ha, or at least US\$4.6 billion for the Indonesia's 2.5-million-ha peatland restoration initiative. This amount represented many-fold the level of funding that had been allocated at that time for restoration from Indonesian and international donor budgets. Likely benefits that were discussed included fire prevention through hydrological restoration, mitigation of water pollution, improvement of water quality, enhanced carbon sequestration by restoring degraded peatlands, biodiversity conservation by reestablishing habitats, and supporting sustainable livelihoods for local communities through eco-friendly economic activities.

In the study of (Puspitaloka et al., 2021), the cost structure of peatland restoration projects in Central Kalimantan was examined, revealing that indirect costs (including addressing social, economic and ecological challenges as well as opportunity costs) constituted a significant portion of total expenses, ranging from 34 % to 45 % in the two projects that they assessed. The authors highlighted that while direct costs for implementing restoration activities were readily recognized, indirect costs were often overlooked. This underscores the importance of considering both direct and indirect costs in the overall analysis of restoration initiatives. The study provided specific monetary findings for peatland restoration projects, with gross costs ranging between US \$16–43/ha and US\$313–450/ha, depending on the level of challenge experienced in each project. Puspitaloka et al. (2021) also analyzed the fire prevention benefits of restoration by reducing wildfire risks in Central Kalimantan, water pollution mitigation through improved

hydrological filtering, and carbon sequestration potential of restored peatlands as carbon sinks. This study appears to make it challenging to determine the exact numbers used but dividing the total gross costs (Table 1) by the restoration area (Table 1) (Puspitaloka et al., 2021) suggests range between US\$16–43/ha and US\$313–450/ha, which are notably lower than those in other studies.

The next paper (Kiely et al., 2021) focussed on quantifying the economic benefits of peatland restoration by assessing the reduction in losses and damage caused by fires, including property damage, health impacts, and land cover damage. It quantified the economic gains of restoration in monetary terms, including reduced fire damage losses (assuming NPV's of US\$4,079/ha for forest, US\$8,885/ha for oil palm, US\$1,662/ha for rubber, US\$827/ha for cropping, US\$7,713/ha for logging, and US\$1,206/ha for wood fibre), reduced CO₂ emissions (based on US\$11.80/t CO₂-e), and reduced human health impacts (assuming a disability adjusted life year value of US\$4,710), enabling cost-benefit comparisons. Emphasis was placed on evaluating the direct economic benefits of restoration, particularly in fire prevention and damage reduction. Regarding costs, the study used direct costs of canal blocking (though the actual amount was not specified) and assumed that buy-back reflected the opportunity costs of oil palm (US\$3,077–\$10,000/ha), wood fibre (US\$418–\$1,357/ha), and agriculture (US \$237–981). One such measure proposed is the restoration of degraded peatlands, which could significantly reduce economic losses associated with fires. By restoring and rewetting 2.49 million ha of degraded peatland, the study estimated a potential reduction in economic losses of US\$8.4 billion, showcasing the benefits of peatland restoration efforts in Indonesia (Kiely et al., 2021). The study also found that the six largest fire events during 2004–2015 incurred economic losses of US\$93.9 billion, attributed to damage across various sectors including agriculture, forestry, trade, tourism, transportation, manufacturing, and the environment. Costs related to fire suppression, short-term health impacts, and school closures were also included in their analysis.

Taking a more holistic approach, Januar et al. (2023) conducted a cost-benefit analysis comparing peatland management scenarios in Central Kalimantan. They evaluated two peatland management scenarios that aimed to compare business as usual with enhanced restoration efforts to reduce carbon emissions, as well as assist with fire prevention, pollution reduction, and improve ES like tourism and collection of peat-friendly plant species, highlighting the diverse benefits of restoration efforts in Central Kalimantan. The study compared two scenarios: Scenario I, reflecting current management practices, and Scenario II, proposing enhanced peatland rewetting, paludiculture, and cessation of drainage-based activities. Results indicated that Scenario II yielded a lower average NPV over 25 years, but higher average NPV over the long term (50 years), suggesting longer term societal welfare is increased when conservation principles are prioritized. Aligning the provincial land use plan with Scenario II could result in negative emissions from the Kahayan-Sebangau Peat Hydrological Unit (Januar et al., 2023). The study underscored the importance of integrating conservation principles into regional land use planning, enhancing direct peatland use value, and fostering restoration efforts through institutional alignment. Additionally, establishing a carbon monetary value to reflect climate goals and considering local community aspirations during land use transitions were highlighted. Most of their detailed cost and benefit assumptions are not clear from the paper or supplementary material, but they assumed BRG regulation cost of rewetting of US\$1,725.93/ha, and a price of carbon of US\$10.90/t CO₂-e.

The study by (Rossita et al., 2021) estimated the direct costs of peatland restoration in the Gaung-Batang Tuaka Peat Hydrological Unit (KHG), Riau. They noted that the total expenditure incurred in restoration through the BRG was US\$20.9 million for reforestation, rehabilitation of degraded areas, infrastructure development, and other activities aimed at restoring the peatland ecosystem (excluding restoration payments required from private holdings and concession areas and communities in the KHG). The study focused on quantifying the

monetary value to the ES from peat, particularly provisioning and carbon regulating services, of the Gaung-Batang Tuaka Peat Hydrological Unit (KHG). Within the System of Environmental-Economic Accounting (SEEA) framework, ES are regarded as benefits when utilized by beneficiaries of the ecosystem. Consequently, provisioning services were valued exclusively for cultivated land, whereas carbon services were calculated for the entire study area (benefiting global stakeholders). The study found that the annual monetary worth of provisioning services post-2010 remained consistent at around US\$30.3 million annually. However, the forfeiture of social benefits from carbon emissions significantly surpassed the value of provisioning services, resulting in an annual loss of US\$628 million, based on a social cost of carbon of US \$38/tCO₂-e, and emissions calculated from burning losses, peat decomposition rates of different land uses, and carbon emissions from change of land use. The findings revealed a trade-off scenario between provisioning services and carbon services, wherein the monetary value of provisioning services exhibited a slower growth rate (US\$0.50 million/year) compared to the monetary loss attributed to the decline in carbon services (US\$5.28 million/year), significantly surpassing the monetary value of provisioning services (Rossita et al., 2021).

The study of Tarigan et al. (2021) quantified various ES (excluding biodiversity) in three primary categories: provisioning services, carbon regulation, and hydrological regulation. Provisioning services account for 19 % of the total ES, while carbon regulation emerges as the most critical service, contributing a substantial 70 %. Hydrological regulation, on the other hand, contributes 11 % to the overall ES. To evaluate the economic implications of peatland management, the study compared three distinct scenarios: Scenario 1 involved no peatland utilization, Scenario 2 focused on peatland restoration through the cultivation of paludiculture crops, and Scenario 3 explored the consequences of utilizing peatlands for monoculture crops, such as oil palm plantations. The findings reveal that Scenario 2, which promotes peatland restoration, offered superior ES compared to Scenario 3, where monoculture practices are employed. Notably, the analysis indicates that Scenario 1 was not more beneficial than Scenario 2 across various combinations of social costs of carbon emissions (ranging from US\$52.7 to US\$107.4) and discount rates (between 5 % and 10 %). While the study did not provide specific monetary values for the ES, it strongly suggested that the long-term economic benefits associated with restoring peatlands through paludiculture significantly outweigh the short-term financial gains from monoculture practices (Tarigan et al., 2021).

5.4. Ex-ante vs ex-post approaches

Evaluating the costs and benefits of ecosystem restoration typically involves two approaches: ex-ante and ex-post monetary valuation studies. Ex-ante studies assess the expected costs and benefits of restoration projects before their implementation, offering insights into potential outcomes and helping stakeholders make informed decisions. These studies can guide strategic planning, assess risks, and prioritize resource allocation. However, they rely on projections and assumptions, which can introduce uncertainties, and often face challenges like data gaps and the dynamic nature of environmental factors such as climate change. In contrast, ex-post studies evaluate restoration efforts after implementation, using real-world data to analyze actual costs, outcomes, and challenges. This approach provides practical insights grounded in empirical evidence, enabling an understanding of the realized impacts and lessons learned. However, ex-post evaluations can be constrained by limited control over variables and risks such as hindsight bias and incomplete data on long-term impacts.

Seven of the reviewed studies (Budiharta et al., 2018; Hansson & Dargusch, 2017; Januar et al., 2023; Kiely et al., 2021; Lin et al., 2017; Schaafsma et al., 2017; Tarigan et al., 2021) used an ex-ante approach, projecting costs and benefits of peatland restoration before implementation. These studies highlighted the ability of ex-ante evaluations

to inform proactive decision-making by estimating the anticipated impacts of restoration efforts and assessing risks associated with these interventions. They also emphasized how ex-ante methods can prioritize investment by comparing potential projects based on their expected returns. However, the reliance on assumptions and models introduces uncertainties, particularly regarding long-term ecological and economic dynamics. Additionally, the highly labor-intensive nature of restoration was a common theme, with activities such as rewetting, fire prevention, and biodiversity monitoring representing significant and ongoing costs. This underscores the need for robust and comprehensive resource planning in ex-ante analyses.

Two studies (Puspitaloka et al., 2021; Rossita et al., 2021) adopted an ex-post approach, analyzing past restoration efforts. These studies leveraged actual government and project data, enabling a detailed evaluation of costs and governance structures. For instance, Puspitaloka et al. (2021) explored the challenges and governance alternatives in peatland restoration, while Rossita et al. (2021) assessed restoration costs from state budgets and emphasized the importance of securing sustainable funding and stakeholder involvement. Such ex-post evaluations provide valuable insights into the effectiveness of restoration strategies, highlighting lessons learned and potential areas for improvement. However, they noted challenges in accounting for long-term ecological changes, the availability of reliable data, and the potential influence of confounding variables in analyzing outcomes.

6. Gaps in approaches and ways forward

The outcomes from this section include a range of opportunity costs, total costs, and benefits of peatland restoration, along with other key considerations, that can be integrated to offer a comprehensive approach to economic evaluation. These limitations reveal areas for methodological improvement and gaps that future research needs to address to refine existing approaches and expand findings. This section presents a nuanced understanding of the research context and contributes to the evolving knowledge base in peatland restoration economics.

6.1. Opportunity costs

Monetary valuation studies focusing on peatland restoration often neglect the crucial aspect of opportunity costs. These costs, representing potential benefits forgone when choosing one course of action over alternatives, are fundamental for a comprehensive economic evaluation of restoration initiatives. Failure to consider opportunity costs can undermine the accuracy and relevance of valuation estimates. The opportunity cost of restoration refers to the difference in land value between its highest and best use before and after restoration efforts (Wilson et al., 2012). It significantly influences landholders' decisions regarding land use. Therefore, understanding opportunity costs is pivotal for several reasons. Firstly, restoration initiatives entail trade-offs between land-use options like agriculture, forestry, or industrial development. Neglecting the economic benefits associated with these alternative uses would inevitably result in a spurious understanding of restoration costs, which would likely be significantly higher. Secondly, accounting for opportunity costs ensures a balanced assessment, aiding decision-makers in evaluating trade-offs and making informed choices aligned with broader economic, social, and environmental objectives. Thirdly, incorporating opportunity costs helps identify potential conflicts among stakeholders, such as local communities or industry sectors, concerned about the impact on their economic interests. Addressing these concerns enhances the social acceptability and sustainability of restoration initiatives. Compensation may be necessary to mitigate adverse ecological and social consequences resulting from missed economic opportunities. However, opportunity costs can be minimized by targeting restoration efforts towards marginal or degraded lands with limited alternative uses or commercial potential.

Seven out of the nine papers reviewed did not explicitly consider or

quantify opportunity costs associated with peatland restoration. While these studies offered valuable insights into various aspects such as local preferences, willingness to pay, financial costs, and potential economic benefits, none comprehensively explored the potential trade-offs or forgone opportunities resulting from the proposed restoration programs.

In contrast, the studies by (Budiharta et al., 2018; Tarigan et al., 2021): 1) estimated the cost of restoring degraded deep peatlands for carbon offsetting purposes in the context of industrial oil palm development, acknowledged the opportunity cost of forgone palm oil production (Budiharta et al., 2018); 2) evaluated the trade-offs between utilizing peatlands for short-term economic gains, such as monoculture crop production, and the long-term benefits associated with peatland restoration and the cultivation of paludiculture crops (Tarigan et al., 2021). Furthermore, the focus of that study on net present value calculations incorporated the concept of opportunity costs by evaluating the economic implications of different scenarios over time (Tarigan et al., 2021). The consideration of opportunity costs is a critical aspect of these studies' analysis, as it underscores the need for sustainable land-use practices that prioritize long-term ecological and economic health. By considering the potential economic benefits of continued oil-palm cultivation and by quantifying the ES provided by different land-use scenarios, these studies accounted for the opportunity costs associated with peatland utilization and provided a more comprehensive assessment of the trade-offs involved in pursuing peatland restoration (Budiharta et al., 2018; Tarigan et al., 2021).

6.2. Total costs and benefits

The importance of capturing the total economic value of peatland restoration cannot be overstated. By considering the full spectrum of costs and benefits, decision-makers can make more informed choices, prioritize investments, and develop policies that maximize net societal welfare. Furthermore, a comprehensive valuation can reveal the true magnitude of the potential gains from restoration efforts, thereby garnering broader support and mobilizing resources from diverse stakeholders.

However, several studies (Hansson & Dargusch, 2017; Lin et al., 2017; Schaafsma et al., 2017) primarily focused on specific aspects of peatland restoration, such as local preferences, willingness to pay for haze mitigation, or financial costs of restoration programs. Tarigan et al. (2021) focused on assessing and quantifying the ES provided by different peatland management scenarios, particularly emphasizing the benefits of restoration through the cultivation of paludiculture crops, such as jelutong. While these studies provided valuable insights within their respective scopes, they did not attempt to capture the total economic value of restoration initiatives. Other studies, like Budiharta et al. (2018) and Januar et al. (2023), took a more holistic approach by considering multiple dimensions, including carbon sequestration, biodiversity conservation, and other ES. However, even these studies acknowledged the inherent challenges and limitations in quantifying and comparing diverse factors, potentially leading to an incomplete or biased assessment of the total economic value.

Despite these challenges, capturing the total economic value of peatland restoration remains critical for informed decision-making and sustainable resource management. Addressing these challenges will likely require transdisciplinary collaboration among those who value peatlands for their different forms and functions. Advancements in valuation methodologies will require improved data collection and monitoring efforts, and enhanced stakeholder engagement processes.

6.3. Additional important considerations

Certainly, above limitations are not in any way exhaustive. There are other factors that could significantly influence cost estimates of peatland restoration activities. Some of them include site-specific factors, such as accessibility, peatland depth, hydrology, and degradation extent.

Additionally, the scale and scope of restoration projects can affect cost estimates, with potential challenges in directly scaling or transferring costs between projects. Temporal considerations, including changes in prices, technologies, or economic conditions over the long term, also play a significant role in defining the feasibility of restoration. Furthermore, indirect and intangible costs, such as impacts on cultural values or ES, are difficult to quantify monetarily and may not be fully accounted for.

Similarly, benefit estimates face limitations. Valuation methodologies used, such as contingent valuation or cost-benefit analysis, may not fully capture the complexities of ES and societal benefits. Limited data availability and quality, particularly for emerging practices like paludiculture or ecotourism, contribute to uncertainties in benefit estimates. Spatial and temporal variations in benefits across regions and time scales may not be adequately considered. Interdependencies and double counting of benefits, as well as non-monetary benefits like cultural values, present additional challenges to accurate estimation.

Therefore, future research on peatland restoration should prioritize developing integrated models that capture both spatiotemporal factors and long-term dynamics. Site-specific variables such as hydrology, peatland depth, accessibility, and degradation should be incorporated through the use of Geographic Information Systems (GIS) and remote sensing technologies, allowing for more accurate spatial representation. Furthermore, economic models should integrate temporal changes, such as price fluctuations, technological developments, and evolving environmental conditions, with sensitivity analysis to assess uncertainties. Additionally, studies should explore how intangible costs, such as cultural values and ES, can be quantified, enriching restoration cost-benefit assessments. This comprehensive approach will provide more robust, context-specific, and future-proof cost-benefit analyses for peatland restoration efforts.

Indonesia is at a pivotal junction in its adoption of new market mechanisms that support the stewardship of nature. Emerging carbon market regulations are attracting a rush of speculative investors. These investors aim to apply nature-based solutions to their clients' net-zero commitments. Investors may be able to charge higher prices for their carbon credits by claiming their investments also achieve biodiversity benefits for communities. However, currently the regulations and prices are in flux. As regulations and standards evolve, there is opportunity for local institutions to co-develop benefit sharing arrangements. This would in effect, provide new instrumental values for conserving biodiversity. There are synergistic opportunities, as new markets may incentivize the alleviation of tenure conflicts, a deep and ongoing obstacle to the entwined outcomes of prosperity, self-determination and sustainable development (Riggs et al., 2016). For instance, social forestry is a tenure already attracting investors interested in carbon plus non-carbon benefit-sharing agreements with local people in peatlands. To support the effective implementation of such initiatives, a clearer and more comprehensive understanding of peatland values is essential. This would enable the identification of coherent, equitable pathways that integrate both the financial and economic dimensions of peatland restoration, ultimately leading to more sustainable and restorative economic outcomes for Indonesia's peatlands.

7. Key limitations of the study and conclusion

One limitation of this review is the restriction to English-language publications, which may lead to an incomplete representation of research on peatland restoration costs and benefits, particularly in Indonesia, where relevant studies and grey literature may be published in Indonesian. While this choice was made to ensure accessibility and consistent interpretation, it is acknowledged that excluding non-English sources might result in missed insights and data that could further contextualize and deepen the findings. Future reviews could expand the language criteria to include Indonesian and other regional languages, potentially uncovering additional studies and broadening the

understanding of restoration economics in diverse local contexts. This expanded scope may offer a more comprehensive picture and help bridge knowledge gaps in the global literature on peatland restoration.

This review is limited by the small number of studies – only nine – that specifically quantify the monetary costs and benefits of peatland restoration in Indonesia, largely due to our selective scope. Our analysis draws solely from peer-reviewed literature, excluding research reports and findings published in grey literature. While numerous studies address peatland restoration, most focus on ecological, social, or policy aspects over direct economic valuation, resulting in a narrow data pool that may limit generalizability. While these limitations are important to acknowledge, we feel that they do not detract from the key messages from the study.

The literature was systematically reviewed to evaluate the economic costs and benefits of various peatland restoration methods in Indonesia. The obtained monetary estimates, ranging from millions to billions of dollars, underscore the substantial economic stakes involved in peatland restoration effort, but also reveal the lack of clarity and common-understanding of the costs. Restoration is a costly undertaking and requires shared responsibility among key stakeholders, including the government, private sector, and other development partners. We see a need for research that contributes towards more systemic understanding of the value of peatland among these governing actors. Additionally, there is a need for innovative financing mechanisms and business models to encourage broader stakeholder participation and make the enterprise financially attractive (Rochmayanto, 2021).

While each of the studies reviewed here employed different methodologies and focused on various aspects of restoration, their collective findings highlight the significant costs required for effective restoration initiatives, as well as the potential economic benefits accrued through environmental conservation, climate change mitigation, and sustainable land management. As policymakers and stakeholders navigate the complex landscape of peatland restoration, these economic valuations serve as crucial inputs, complemented by a holistic consideration of ecological, social, and cultural factors to ensure informed decision-making and sustainable outcomes. The comparative assessment of the economic dimensions of these restoration methods, considering their implications over time, aimed to provide evidence-based insights for decision-making processes related to peatland restoration initiatives, fostering more informed and sustainable interventions.

The reviewed studies explored diverse aspects of peatland restoration, including carbon sequestration potential, fire prevention benefits, water pollution mitigation, biodiversity conservation, and impacts on local livelihoods and other ES. While some research focused narrowly on specific dimensions like the economic costs or carbon offsetting capabilities, others adopted a more comprehensive approach to capture the interconnected advantages of peatland restoration across multiple spheres. This variety of perspectives highlights the complexity of evaluating restoration initiatives, which necessitates balancing depth of analysis on key aspects with the breadth of understanding derived from a holistic examination of the diverse benefits and trade-offs involved.

It is important to note that each valuation method has its strengths and limitations, and the choice of approach depends on the specific research objectives and contexts. Monetary valuations offer quantitative estimates of economic values, which can inform cost-benefit analyses and investment decisions. However, they may overlook non-monetary values and local perspectives, which are critical for understanding the social acceptability and sustainability of restoration initiatives. Conversely, qualitative field estimation methods can provide valuable insights into local contexts but may not directly translate into economic metrics. Ultimately, a combination of monetary valuation and field estimation methods, as exemplified by the study by Schaafsma et al. (2017), may offer a more holistic understanding of the economic and social dimensions of peatland restoration. Such integrated approaches can inform more comprehensive and inclusive decision-making processes, accounting for both economic feasibility and local stakeholder

perspectives.

Despite valuable insights from the range of studies that we reviewed on peatland restoration valuation, explicit consideration of opportunity costs deserves greater attention. Future studies should account for economic benefits forgone due to restoration efforts to provide a more comprehensive assessment, informing robust decision-making and promoting sustainable peatland management and restoration policies. Considering opportunity costs is crucial in evaluating the trade-offs involved in peatland restoration efforts and understanding the implications of transitioning towards more sustainable land use practices. Given the limitations, it is crucial to interpret and utilize cost and benefit estimates with caution, recognizing potential uncertainties. Further interdisciplinary research, long-term monitoring, and the development of robust valuation methodologies are needed to refine and improve the accuracy of cost and benefit estimates for peatland restoration in Indonesia.

Peatland restoration is a multifaceted endeavour with wide-ranging economic, environmental, and social implications. In essence, studies highlighting multiple peatland restoration aspects provide a comprehensive, holistic view valued by policymakers but are analytically complex. Recognizing the challenges in capturing the total economic value and the ongoing enhancements in valuation methodologies, collaborative efforts among researchers, policymakers, and stakeholders can lead to more comprehensive and robust assessments of peatland restoration initiatives. This, in turn, facilitates the formulation of policies and strategies that optimize resource allocation, maximize societal benefits, and safeguard the invaluable ES provided by healthy peatland ecosystems. Moreover, it is essential to acknowledge that economic valuations, while crucial, should not singularly dictate restoration decisions. A holistic approach that integrates economic considerations with ecological, social, and cultural factors is imperative for achieving sustainable and equitable outcomes.

CRediT authorship contribution statement

Shokhrukh-Mirzo Jalilov: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Yanto Rochmayanto:** Writing – review & editing, Methodology, Investigation. **Dian Charity Hidayat:** Writing – review & editing, Methodology, Investigation. **Jany Tri Raharjo:** Writing – review & editing, Methodology, Investigation. **Daniel Mendham:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition. **James Douglas Langston:** Writing – review & editing, Supervision, Project administration, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ecoser.2024.101693>.

Data availability

No data was used for the research described in the article.

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