

## Analysis of challenges, costs, and governance alternative for peatland restoration in Central Kalimantan, Indonesia

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### ABSTRACT

Restoration of degraded tropical peatland is considered to be one of the most cost-efficient measures in reducing greenhouse gas emissions and conserving biodiversity. Although benefits of restoration are often expected to substantially exceed the costs, most restoration projects are being carried out without clear cost analyses. This study provides empirical assessments of challenges and costs of the four peatland restoration projects managed by different proponents in Central Kalimantan, Indonesia based on key informant interviews, a follow-up survey and document analyses. We also reviewed existing policy contexts that can address some of the challenges to propose a governance alternative to sustain peatland restoration efforts. We found that many ecological challenges of peatland restoration projects were created by drainage canals leaving the peat to be dry and fire prone. Peatland degradation has been exacerbated by human activities and human-caused fires, and restoration efforts have faced many challenges due to lack of secure funding and complexity of governing the project implementation. The key informants we interviewed easily recognized direct costs for implementing restoration activities, but often left out indirect costs of addressing social challenges, such as expenses to engage local communities, in their assessments of the costs. Although our accounting is far from exhaustive, we found that indirect costs can add up to half of the total cost of peatland restoration projects. Current funding mechanisms for these projects mostly rely on international donors and private sectors, which make the long-term sustainability of the projects questionable. We argue that hybrid governance for a green business model, such as restoration and ecosystem services enterprises, with active participation from the public sector should be mainstreamed. The accounting framework developed in this study can be applied in other projects and should be further revised to systematically assess cost-effectiveness of restoration interventions.

### Introduction

Undisturbed and pristine peat is naturally resistant to fire due to their waterlogged condition. However, fire dynamics of peatlands in tropical developing countries, such as Indonesia, are changing (Page and Hooijer, 2016). Human-caused fires in non-fire adapted ecosystems of peatland became recurring phenomena across Indonesia in recent decades (Bowman et al., 2009). Fires, often starting out small in size, are ignited to clear lands to meet unprecedented demands for agricultural lands (Curtis et al., 2018; Knorr et al., 2014). Many small scale fires have cumulative impacts and can spread quickly throughout the landscape due to degraded fire-prone conditions exacerbated by changing climate

(Field et al., 2016). Studies found that stakeholders shaping the changes in peatland fire dynamics are wide ranging from smallholders to international investors with different degree of political power (Carmenta et al., 2017; 2021). Their incentives for fire uses vary as well as their views on potential solutions (Phelps et al., 2021; Purnomo et al., 2017, 2019). These complex socioeconomic factors also complicate peatland restoration efforts under weak governance and contested land tenure (Carmenta et al., 2017, 2020)

Degradation of peatland ecosystems in Indonesia is of global concern for the loss of carbon storage and biodiversity, as well as direct negative effects of fires, such as transboundary air pollution and haze (Baccini et al., 2012; Barlow et al., 2012). For example, the severe fire season in

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2015 in Indonesia generated greenhouse gas (GHG) emission of 1.5 billion Mt CO<sub>2</sub>e (Field et al., 2016) and economic loss of USD 16 billion, which does not include loss of ecosystem services or the impacts to other countries (Glauber et al., 2016). Since then, the Indonesian government made considerable efforts to reduce fires and restore peatland ecosystems through strengthening enforcement of existing laws and regulations, as well as developing new initiatives. For example, the Peatland Restoration Agency (*Badan Restorasi Gambut* - BRG) was established, through the Presidential Decree 2016, with the ambitious target of restoring two million hectares of degraded peatlands within five years. Recently, the President issued a decree that expanded the scope of national peatland restoration timeframe and target, to also include mangrove.

BRG defined the main policy and strategic directions of restoration as the 3Rs approach: Rewetting, Revegetation and Revitalization (BRG, 2016). Restoration projects should be designed with construction of rewetting infrastructure, e.g., canal blocking, to restore peat's hydrological functions; revegetation of degraded peatland with peat-adapted species, e.g., various hardwood, fruit trees, and medicinal plants; revitalization efforts to explore, identify and develop more sustainable alternative livelihood in and nearby degraded peatlands for local communities. Although the 3Rs approach has long been known for its implicit focus on reducing fire risk through 'flooding' the fire-prone, degraded peatland, 'Reducing Fire' was recently added to make the guiding principles the 4Rs (Harrison et al., 2019). In the new approach, BRG also explicitly acknowledged the needs for addressing ecological, social and economic challenges of restoring peatlands. According to a recent study, reducing fire risk is an important project goal recognized by proponents and practitioners of peatland restoration projects along with improving degraded peat conditions (Puspitaloka et al., 2020).

Restoration of degraded land is considered to be one of the most cost-effective measures in reducing GHG emissions (IPBES, 2018). A recent study identified peatland of Indonesia, especially in Kalimantan, as a global restoration hotspot where potential benefits and feasibility of restoration are high (Brancalion et al., 2019). Benefits of restoration are often expected to substantially exceed the costs (De Groot et al., 2013; Global Green Growth Institute, 2015; Glenk and Martin-Ortega, 2018). However, actively restoring degraded ecosystems implies activities that incur costs and most of restoration projects are being carried out without clear cost analyses (Kimball et al., 2015). Accounting of restoration costs combined with clearly defined parameters of success is crucial: 1) to justify the costs of restoration as an investment with positive return (De Groot et al., 2013); 2) to support a better decision-making process (Kimball et al., 2015); 3) to assess the effectiveness of different policy models to sustain ecological restoration efforts (Iftekhar et al., 2016); 4) to help configure resource allocation and increase efficiency of the projects (Brancalion et al., 2019; Holl and Howarth, 2000). The challenges for accurately estimating the costs include a great deal of scientific uncertainties and data gaps (Moxey and Moran, 2014; Glenk and Martin-Ortega, 2018) and high variability of costs depending on ecological and social contexts of projects (Glenk and Martin-Ortega, 2018). The cost variations are due to specific ecosystem conditions and restoration goals that demand different approaches of restoration, as well as different values of land and labor across regions (De Groot et al., 2013). The environmental and spatial variations affect costs, cost-effectiveness and success of restoration projects (Kimball et al., 2015).

Different approaches for restoring degraded peatlands, such as active and passive restoration, carry different cost consequences. Applying a passive restoration approach, which is no action other than removing the drivers of degradation, tends to be considerably cheaper compared to active restoration approaches, such as tree planting. Still, passive restoration involves some upfront investment costs, such as installing and repairing fences, as well as opportunity costs (Zahawi et al., 2014) and costs for continuous monitoring. The opportunity costs are financial values of more lucrative alternative land uses. An active restoration

approach would require more upfront investment to conduct site preparation, seeding and fencing (Iftekhar et al., 2016). Site preparation activities to restore peatland in Indonesia include those for surveying and determining location, scheduling planting, transporting seeds, and constructing planting lines (Wibisono and Dohong, 2017). If the restoration approach includes interventions to reduce anthropogenic pressure through development of sustainable livelihood, it also involves promoting adoption of zero burning technique, which is mandated in the government programs. Restoration interventions would also incur the costs to implement tree planting practices and other restoration treatments (Glenk and Martin-Ortega, 2018) and manage, administer and monitor restoration activities and their outcomes (Iftekhar et al., 2016). Choosing a restoration approach to implement should be planned and evaluated to ensure its effectiveness (Rohr et al., 2018). Different restoration approaches also differ in their cost structure, in terms of direct and indirect costs. Direct costs are those associated with implementing ecological restoration interventions, while indirect costs are those for assisting recovery of ecosystem, such as addressing social, economic, and ecological challenges, as well as transaction costs (Iftekhar et al., 2016; Glenk and Martin-Ortega, 2018) and opportunity costs (Moxey and Moran, 2014; Iftekhar et al., 2016; Glenk and Martin-Ortega, 2018). Direct costs are relatively straightforward to account for in planning restoration activities, while indirect costs are usually left out in cost calculations (Spielman, 2018). Both direct and indirect costs should be considered for proper planning of restoration projects (Moxey and Moran, 2014; Iftekhar et al., 2016; Glenk and Martin-Ortega, 2018).

There have been several studies that identified ecological and social challenges of peatland restoration (Harrison et al., 2019). Many peatlands in Indonesia are degraded due to human activities, such as farming, hunting, timber and peat extraction, which involved draining water out of peatlands with the construction of drainage canals (Joosten et al., 2016).

Various human uses of peatlands that adapted to the degraded state, such as using the drainage canals for transportation, may create conflicts with the restoration efforts (Meijaard et al., 2013; Osaki et al., 2016a, 2016b; Dommoin et al., 2016; Hergoualc'h et al., 2017). Dried out peat may become hydrophobic and thus resist rewetting, which is one of the main treatments in peatland restoration, due to the loss of water holding capacity after an extended period of drying and sun exposure (Andarjoesse, 1988). Peatland restoration projects can promote supportive conditions for new peat to be initiated and accumulated, although peat accumulation is very slow (Page et al., 2004). These challenges would be hard to address in the short term (i.e., during or within project duration – which are typically five years), thus sustaining the efforts beyond the planned duration is necessary (Puspitaloka et al., 2020). Considering that each restoration project may face unique socioeconomic and ecological challenges, developing a contingency plan is necessary with allowance of additional costs.

Previous studies reported a general cost assessment of peatland restoration projects in Indonesia using a government project as a case study (Hansson and Dargusch, 2017) and explored financing options, such as private sector investment (Goib et al., 2018), green bonds and blended financing (Sari et al., 2020). However, there has been no empirical study that documented ecological, social and economic challenges from project practitioners' perspectives and reported actual costs for addressing them. This paper fills that gap by providing empirical assessments of challenges that different proponents in Central Kalimantan, Indonesia face for managing peatland restoration projects. We describe the challenges in relation to various cost components and estimate their range. A better understanding of challenges and costs of restoration would help explore more options for capitalizing the restoration momentum under existing regulations and mechanisms, and for bringing diverse funding to restoration projects.

**Table 1**  
Profile of the study area.

Profile	Project A (NGO and National Park)	Project B (Government and Int. Dev. Agency)	Project C (Private Company and NGO)	Project D (Private Company and University)
Ultimate restoration goal*	Ecological and social goals, protection from threats, and lessons learned for others	Ecological and social goals, reducing GHG emission	Ecological and social goals, carbon trading, and reducing GHG emission	Ecological and social goals, and carbon trading
Total size (in ha)**	568,700	660,140	157,722	25,800
Estimate size of restoration (in ha)***	300,000	660,140	157,722	25,000
Length of planned restoration (in years)	30	5	60	25
Starting year	2004	2016	2013	2013
Primary funding sources	Grants NGO's international and national chapter	Government budget Grants	Private investment	Private investment

\* More information and detail analyses can be found in Puspitaloka et al. (2020). Ecological goals were defined as restoring the ecosystem to its intact condition prior to the disturbance. Social goals were defined as reducing the anthropogenic pressures through, for example, community development.

\*\* based on desk study in 2017

\*\*\* based on key informant interview in 2017

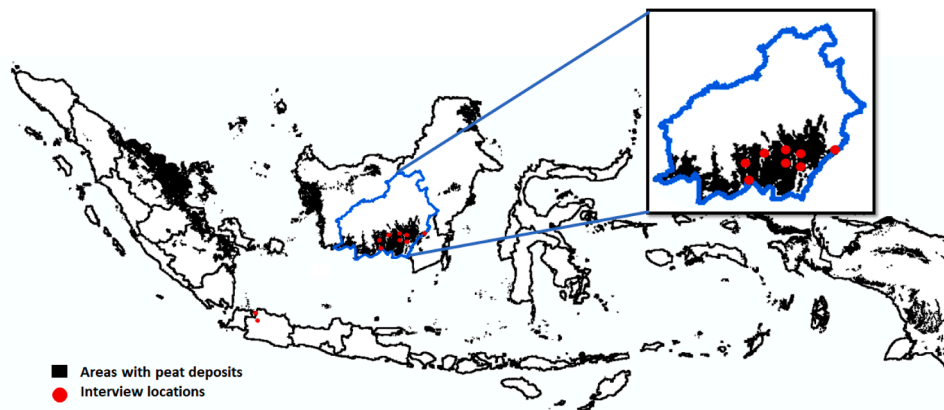


Fig. 1. Our study site in Central Kalimantan Province and the headquarter office (DKI Jakarta and West Java Province).

## Methods

### Study area

This study focused on the four different peatland restoration projects at Central Kalimantan Province, Indonesia, which is the third largest province with 2.7 million ha of peatland (Ministry of Agriculture, 2011). Central Kalimantan Province is one of priority areas for peatland restoration recognized by the Indonesian government. There are at least four different peatland restoration projects in Central Kalimantan out of 20+ projects being implemented in Indonesia as of 2017. These projects are carried out by various proponents and the challenges that they face are context dependent, influenced by the socio-economic and ecological conditions of the specific locations where each project operates. The four projects are managed by: 1) national park partnered with a non-governmental organization (NGO) (hereafter referred as project A), 2) government partnered with an international development agency (hereafter referred as project B), 3) private sector partnered with an NGO (hereafter referred as project C) and 4) private sector partnered with a university (hereafter referred as project D) (Table 1). The four projects together cover more than one million hectares of peatland across six districts (Palangkaraya, Pulang Pisau, Katingan, East Kotawaringin, South Barito and East Barito). We also carried out interviews and visits to the headquarter offices of NGOs and BRG in Special Capital Region of Jakarta and West Java Province (Fig. 1). We focused on the challenges faced by each proponent and how these challenges affect the estimated costs to restore degraded peatland. We explored the possible funding options by reviewing relevant policies and existing mechanisms in Indonesia. This study protocol has been reviewed and approved by

Indonesia Ministry of Home Affairs, and the lead author's home institution's Institutional Review Board (IRB) for human subject research.

### Approach and methods

We triangulated the semi-structured interviews, literature review, and follow-up questionnaire to analyze the details of the restoration activities, challenges, and costs. For the interviews, we employed purposive sampling where the key informants were selected based on specific purposes associated with research questions (Teddlie, 2009). We interviewed 47 key informants who hold formal positions in the respective projects, have knowledge relevant to the research and are willing to share (total 39 hours of interview). The key informants represent 20 institutions: restoration and community forums (23%), national park management (17%), NGO (17%), private concessions (17%), local governments (13%), national government agency (9%), forest management unit (2%), and university (2%). We used an interview prompt with open-ended questions (Jamshed, 2014) for semi-structured interviews. This type of questions can increase the response rate and enhance richness of the data (O' Cathain and Thomas, 2004). The open-ended questions are consisted of the core and supported questions. The core questions asked about site condition, fire regime history, restoration goals, practices and challenges. The supported questions were a follow up to the key informants' answers. Prior to interviews, we explained the purpose of the research and seek informed consent and approval for interview and recoding. We audio-recorded the interviews then transcribed the recordings using F5 Transcription PRO (Haselberger, 2018). The transcripts were coded using NVivo for Mac version 11.4.2 (QSR International Pty Ltd, 2017) to

identify the pattern and emerging themes under topics of 'pre-restoration activity', 'restoration activity', 'challenges', 'funding', and 'potential time-frame to achieve restored peatland'.

Based on the interview results, we built an accounting framework for different costs reported for pre-restoration and main restoration activities and for addressing challenges. We developed a questionnaire to confirm the accounting framework and estimate actual expenses. We sent the questionnaire to 8 proponents who manage peatland restoration projects on ground. Given the sensitivity of financial information, the response rate for the follow-up survey was low (3 out of 8 for Projects A and D, 37.5% return rate). We used the information to construct a cash outflow using Projects A (NGO-sourced funding) and D (private sector-sourced funding). The managing coordinators of the two projects provided feedbacks on the accounting framework and financial information. Project A started long before BRG in 2004 with international funding for biodiversity conservation, while Project D was initiated more recently by a private sector with an expectation of eventual carbon trading. To project cash outflow over the project duration, we constructed different scenarios of varying social-ecological conditions and extended project durations.

To evaluate potential financing options for peatland restoration projects, we identified the current funding sources of the restoration projects from the key informant interviews, and reviewed the Government of Indonesia policy documents, such as the moratorium on new permits and improving primary natural forest and peatland (Presidential Instruction No. 5/2019), Indonesia's first nationally determined contribution (Government of Indonesia, 2016), policies on establishment of state enterprises (Government of Indonesia Decree No. 72/2016 and No. 54/2017, Ministry of Villages, Rural Areas Development and Transmigration No. 4/2015), policies on environmental services enterprises including restoration enterprises (The Ministry of Environment and Forestry/MoEF Decree P.11/2013, P.31/2014, P.8/2015, P.28/2018), and policy on delegation of authority in issuance of concessionaire licenses (MoEF Decree on P.6/2020). We reviewed the literature on restoration financing schemes worldwide (Food and Agriculture Organization of the United Nations/FAO and United Nations Convention to Combat Desertification/UNCCD, 2015; Egan and Seidenberg, 2009; Jacob et al., 2017; Lucas, 2015; Borgström et al., 2016), and progress of carbon trade (World Bank, 2020; Forest Trends Ecosystem Marketplace, 2020). We also reviewed the MoEF (2019) statistics report with focus on restoration and non-restoration license concessionaire for the extents of their operation areas and total value of investments.

## Results

### 3.1. Challenges of peatland restoration

Although the restoration projects are located in different districts in Central Kalimantan, their land use history are relatively similar. The key informants acknowledged that peatland degradation can be traced back to decades ago when the legal and illegal timber harvesting activities began, then followed with the Mega Rice Project in 1996.<sup>1</sup> During the New Order government, the government's Pelita program in 1984-1989 planned 230,000 household (about one million population) to Central Kalimantan Province (Levang, 2003).<sup>2</sup> This program exacerbated the anthropogenic pressures on the peatland. We have coded and grouped similar challenges, although specific issues and their gravity differed among the four projects (Table 3).

<sup>1</sup> Mega Rice Project was a government initiative to convert one million hectares of peatland for agriculture.

<sup>2</sup> Transmigration program was a government initiative to relocate poor farmers in the densely populated areas, such as Java island, to scarcely populated areas, such as Kalimantan.

Each of the challenges documented in Table 3 was assessed for its percentage of the key informants noting the challenges. Over 95% of key informants of all four projects reported the presence of anthropogenic challenges. Anthropogenic challenges refer to those related to the community acceptance and participation, as well as human activities for commercial or domestic purposes competing with restoration activities. All projects reported livelihood activities, such as fishing, hunting, grazing and illegal logging, and negative attitude of local communities towards the restoration project. Project A reported that the local communities perceived the canal blocking activities to be restraining their livelihood access. Other projects such as Project C reported that complex demands from neighboring communities in the buffer areas (34 villages) could not be accommodated in the project plan, which resulted in community rejections. Despite the help from a local NGO as the supporting partner, it was costly to address each of these 34 villages' demands. These findings are consistent with previous studies that reported a number of canal blocking facilities built as part of restoration efforts were being destroyed and removed by local communities in Central Kalimantan (Dohong, 2016).

Most of the key informants (over 77%) also reported facing ecological challenges, which refer to those related to ecological conditions of peatland, such as severely degraded peatland that resisting rewetting, ecological impacts of existing canals and drainages, human activities, and limited accessibilities within the restoration area. Project A reported a timber concession in the past constructed canals for transporting the logs which then drained water out of the area. Project B noted the history of peatland conversion, involving the massive construction of drainage canals, in the era of Mega Rice Project causing the peatland in their site to be severely degraded and fire prone. Project D indicated the impact of grazing activities towards soil compaction in some of their regions. Proponents of Project D perceived the access difficulties inhibit their progress in replanting. They tested aerial seeding to overcome this issue. Although the seeds were pre-tested for their adaptability to peat soil, the survival rate has been extremely low at about 2% despite the high cost.

Fires in peatland create smoke and haze and are difficult to extinguish. Many key informants (over 74%) noted the challenges related to recurring fires, difficulties for suppressing fires and their impacts. In most cases, fire fighters encountered both surface and belowground fires, which can persist weeks or months depending on the thickness of dry peat that serves as belowground fuel. The longer fire occurred, the more vegetation was destroyed. The key informants of Projects A and C elaborated that fires damaged the trees they have planted for revegetation purposes. Recurring fires would destroy most of the trees, which they perceived as more harmful than the threats of illegal logging. It also threatened biodiversity, including the critically endangered clouded leopard (*Neofelis nebulosa*) in Project A.<sup>3</sup> In project C, with carbon trading as its business goal, recurring fires was the major threat toward potential carbon trading as it would disrupt the emission reduction efforts and lower their carbon credits, in addition to the impacts on replanting activities.

We have grouped challenges described by key informant under the major themes. However, anthropogenic, ecological and fire related challenges are interconnected. Interviewees of all four projects agreed that the ecological challenges were created by drainage canals leaving the peat to be dry and fire prone. Local communities ignite fires to clear out vegetation blocking the access for fishing and to prepare land for agricultural crops. These fires spread throughout the landscape in dry and fire-prone periods, causing recurring and large-scale fires, especially during the long drought in recent years. The ecological challenges were aggravated by anthropogenic challenges described above, and the presence of active settlements within the Project A.

Another major theme noted was limited access to capital and

<sup>3</sup> Clouded leopard is designated as 'vulnerable to extinction' by IUCN.

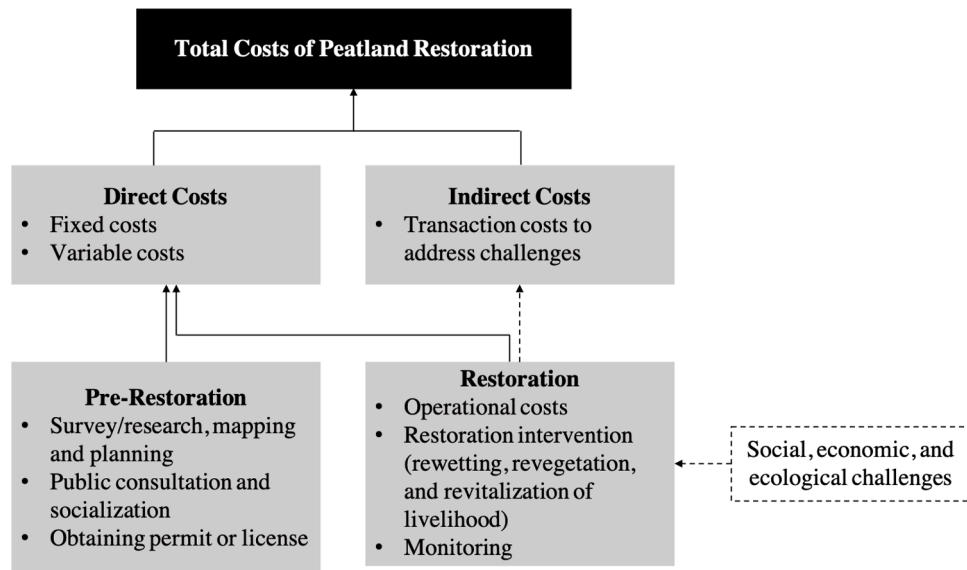


Fig. 2. Accounting framework of restoration costs.

continuous funding (noted by 74% of the key informants). Funding constraint was an issue across all the projects due to the duration needed to successfully restoring peatland. The key informants across different projects, who are project managers and implementers, defined a successful restoration as restoring the ecosystem into its former condition prior to disturbance. Their goals include both ecological and social elements to restore the functions of peatland and improve community welfare and participation.<sup>4</sup> However, it may not be possible to achieve the pristine peatland condition if the peatlands have been severely degraded to be in the ‘irreversible drying’ stage where it becomes hydrophobic (Andariesse, 1988; Huat et al., 2014). In that case, restoration efforts should aim to create supportive condition to allow for a new accumulation of peat. Restoration projects in Central Kalimantan were planned to be carried out in a short term (5-60 years). The key informants we interviewed estimated that many restoration activities would be needed beyond the project durations, and actual durations would vary depending on the degradation level of each site. All projects expect to incur the costs beyond their project durations if they want to maintain the invested restoration facilities and efforts. Projects C and D exemplified the most specific, tangible challenges in funding. Both projects were initiated with carbon trading as their eventual revenue source, but as of 2017 (at the time of the interviews), the regulations on carbon trading mechanism remained unclear and yet to create a supportive business climate. Without carbon trading, the projects would continue to incur costs without revenues, which make the sustainability of the project questionable.

Institutional challenges (noted by 53 of the key informants) referred to the complexity of governing the implementation of restoration projects, which involve complying to central, provincial and local government regulations and engaging various stakeholders. For example, Project B faced many challenges for introducing and mainstreaming peatland restoration concept among their stakeholders. Since peatland restoration was a relatively new concept, they initiated collaboration channels for many institutions to get involved, ranging from international to local level actors, such as a United Nations agency, NGOs, a local government, university, and local communities. Project B also initiated community groups and forums, such as Forum Hapakat Lestari, *Desa Peduli Gambut* (peat care villages), *Masyarakat Peduli Tabat* (canal blocking care community), and *Masyarakat Peduli Api* (fire care

community). These groups worked at different spatial scales and served as platforms to discuss and implement the plans and activities. However, collaboration with many institutions created institutional complexities where information sharing became a challenge. The key informant noted that the institutional challenges stem from fragmented scope of tasks and responsibilities assigned to different agencies, as well as their overlapping and conflicting interests, especially in land use planning and development. Although coded separately, many other challenges, such as lack of law enforcement (40%), spatial plan (35%), technical capacities (34.7%), human resources (32%), and regulations (19%), also exacerbate the institutional challenges and influence the slow progress of the restoration efforts.

#### Accounting framework to estimate the costs of peatland restoration

Restoration efforts initiated/implemented in Central Kalimantan varied in their approaches, sizes, and complexity of the challenges that they face. To systematically assess the costs for various projects, we developed an accounting framework for estimating the total costs of restoration including both direct and indirect costs (Fig. 2). The framework was built using the information from the interviews, then tested using a questionnaire to solicit feedbacks from the key informants on the presence of different cost components, as well as their estimated expenses for each activity. During the interviews, the key informants described various costs to manage and operate the project as well as to perform different restoration activities, particularly rewetting, replanting, revitalization of livelihood and reduction, prevention and suppression of fires. We classified the direct costs associated with restoration activities into fixed and variable costs. Fixed costs are the operational costs of the project committed for the project duration, such as construction costs of restoration facilities, costs of developing and implementing planned/on-going programs, and wages of permanent staff. Variable costs are those varied by the level of outputs and activities, such as transportation costs and wages of temporary staff.

We found that the key informants initially were not fully aware of the cost implications of the activities that they described when asked about the challenges. Although the costs for addressing the challenges were often left out from the overall project cost calculation, it does not mean the absence of the costs. The key informants elaborated the presence of social and economic challenges due to lack of acceptance by local communities and their perception that the restoration facilities restrained their livelihood access. Local communities use fires for

<sup>4</sup> Covered in depth in Puspitaloka et al. (2020)

various livelihood practices and often actively remove or damage restoration facilities. These activities negatively affect the progress of the restoration projects, which led the proponents to innovate or adjust their approach. In most cases, they intensified the programs to engage local communities for educating the benefits of peatland restoration and developing alternative livelihood options to reduce the pressures towards the restoration projects. We specified indirect costs as those transaction costs identified during the interviews for addressing social, economic, and ecological challenges. Additional costs would be incurred if the challenges persist or intensify. We estimated the costs of each activity based on interviews, then developed six scenarios with different level of social, economic, and ecological challenges across spatial-temporal scales and calculated the total costs under each. The scenarios range from no to medium and high levels of challenges (Table 3).

Activities for restoring degraded peatlands occurred in the pre-restoration and restoration stages. Pre-restoration activities were those implemented prior to formally and legally conducting the restoration projects. According to the key informants, the pre-restoration activities included process to obtain permit or license, survey, research, mapping and planning, as well as public consultation and socialization to seek consent and agreements from the community. Main restoration activities are those for rewetting, revegetation, and revitalization of livelihood. To increase community engagement and respond to the challenges, each project formulated their own strategies. These included the tree adoption program, developing trust funds to support alternative livelihood activities, offering agroecology school for farmers to increase environmental awareness, and many more. The pre-restoration and main restoration activities are direct costs, both fixed and variable. Transaction costs for addressing social and ecological challenges are categorized as the indirect costs of restoration, which often overlooked by the key actors.

#### Case studies: Project A and D

We used the findings from interviews with the key informants to identify different costs of peatland restoration and develop the accounting framework described above. We seek to ground-truth the framework with the key informants and estimate the total costs based on actual costs on the ground. However, less than half of the key informants contacted returned the cost survey even after repeated contacts and reminders, which is understandable considering the proprietary nature of financial information. The cost estimations are based on the two projects that reported the total costs and some of their actual costs. We filled in the information gaps, i.e., missing data, omitted cost components, and implication of stated challenges to the costs, with the following assumptions. First, we assumed peatland projects that build restoration facilities and carry out various programs cannot expect noticeable peat accumulation during their project period. Peat accumulation assumed to start in year 11, after the pre-restoration activities (i.e., research and mapping and early community engagement programs to obtain consent) and canal blocking facilities are constructed and community-engagement programs are running. This is based on the interviews with the key informants where they stated that they spent several years in the beginning or before the project just to carry out the pre-restoration activities. The rate of accumulation is expected to be about 1.3 mm/year according to the literature (Rieley et al., 2008), although actual rate of accumulation may vary and different environment conditions would also contribute to the variation. Thus, restoration efforts will have to continue a long term until the peat accumulation target is reached beyond the project duration. Second, we adjusted salary and wages for the profit-oriented projects that were under-reported based on the number of staff that they have. Some financial information, such as taxes and subsidies, management fee, and depreciation costs, were excluded from the calculation due to unavailability of data. We applied a discount rate at 4% per year for Project A (grant-funded) and 9% per year for Project D (private sector-funded) to calculate the present value of future costs with all other variables being

equal (*ceteris paribus*). These rates are conservative as discount rate of 10~12% per year are usually employed by leading development banks when evaluating projects in developing countries (Harrison, 2010).

Peatland restoration projects face many different social, economic and ecological challenges which are site-specific and also affected by macro contexts that the projects operate. We developed three scenarios to estimate the range of restoration costs depending on the level of social, economic and ecological challenges and estimated the costs under each scenario based on the reported costs of different activities. In the “No Challenge” scenario, local communities are assumed to support restoration activities and they would not remove or destroy the canal blocking and avoid the use of fires in peatland-based livelihood and activities. This scenario also assumed a supportive climatic condition, and absence of long drought or fire and that all restoration activities are successful. This scenario functions as a control or boundary of the most optimistic situation. The challenges gradually increased in the “Medium Challenge” and “High Challenge” scenarios, depicting the level of severity and actions required to respond to the challenges. In the “High Challenge” scenarios, which is the most pessimistic, but may be more realistic, we assumed severe and frequent fires affecting replanting efforts and removal of canal blocking affecting rewetting efforts, in addition to local communities rejecting restoration initiatives, which would require a more intensive community-focus development program and socialization. The Medium Challenge scenario assumed that medium severity fire (50% of vegetation destroyed) would occur once during the project period, which means 50% additional cost in replanting and increased costs for fire suppression and prevention as well as for monitoring. The High Challenge scenario assumed that high severity fire (90% of vegetation destroyed) would occur twice during the project duration, which means additional 90% of the costs in replanting and twice more of other costs. Both scenarios assumed additional costs to repair and reconstruct damaged canal blocking infrastructure and additional community development and socialization costs as well as delays in meeting ecological targets of the projects (Table 1, Table 3). For Projects A and D that reported actual costs, we estimated the costs for currently planned project durations (30 years for Project A and 25 years for Project D) with extended project durations: 50 years (No Challenge), 55 years (with Medium Challenge), and 65 years (with High Challenge). We calculated direct and indirect costs under each scenario based on the costs provided by the key informants. However, there may be other costs underrepresented and underreported.

Project A has the ultimate goal of restoring the ecological conditions of peatland and returning the key native species into their habitat. The project also aims for social goals with focus on enhancing community welfare and participation in restoration. We also identified other project goals during the interviews for protecting the ecosystem from threats and provided lessons learnt to other stakeholders. The project aimed to restore about 300,000 ha or 53% of the total site (568,700 ha) within 30 year, with the NGO-funded replanting project covers about 6,900 ha<sup>5</sup> and the remaining replanting is being carried out by the National Park and its partner. In 2017 alone, they have allocated US\$ 168,374<sup>6</sup>, which does not include the costs of pre-restoration activities, such as research and mapping. Project A spent from 2007 to 2015 total US\$ 303,073<sup>4</sup> for restoration activities. Project D also shared similar views on the ecological and social goals to achieve in their restoration. As the project is being carried out in a concession with a business license in carbon sequestration and storage, they specifically mentioned carbon trading as their ultimate goal. The planned to restore about 25,000 ha<sup>7</sup> or 97% of its area (25,800 ha) in 25 years, with the replanting project planned to

<sup>5</sup> Primary data from questionnaire

<sup>6</sup> Primary data, figures shown in constant dollars. The exchange rate used was IDR 14,848 (average exchange rates in September 2020 from the Central Bank of Indonesia).

<sup>7</sup> Personal communication April 6, 2018

cover 20,000 ha.<sup>6</sup> The budget allocated for 2017 alone was US\$ 80,820<sup>4</sup>, excluding the pre-restoration activities (research). The total costs of pre-restoration activities for Project D from 2015 to 2018 was estimated at US\$ 35,022<sup>4</sup> (Table 1).

Using the framework of restoration costs (Fig. 2), we calculated the costs for both projects (Table 4). Across all projects and challenge scenarios, expenses for replanting were consistently the largest spending category, followed by those for rewetting. We estimated the total net costs of restoration for Project A was US\$ 3.1 million for 30 years and 3.5 million for 50 years under “No Challenge” scenario. However, if challenges persist and intensify, the total costs would be about US\$ 4.9 million for 30 years and 5.5 million for 50 years under “High Challenge” scenarios. As the costs gradually increase with higher levels of challenges, the indirect costs would account for 13% to 45% of the total costs.<sup>8</sup> The total costs for Project D was US\$ 7.8 million for 25 years and up to 7.9 million for 50 years under the “No Challenge” scenario. In the “High Challenge” scenario, we estimated the total cost to reach US\$ 11.38 million for 25 years and 11.24 million for 65 years. The indirect costs would account for 9% up to 34% of the total costs.<sup>6</sup> The area of Project A in a National Park is larger than the area of Project D (300,000 ha vs. 25,000 ha), but the extent of the activities in Project A (e.g., planting) was much smaller than Project D. The actors in Project D perceived that the majority of their project area needs active restoration approach, such as planting and extensive community engagement. However, their progress has been slow and the project is severely underfunded. In their technical proposal, the company planned to finance US\$ 17.45 millions of investment, internally sourced from the other branches of the company and externally sourced from investors for 20 out of 25 years of the project’s operation. There is limited information available on how the project would continue to finance its restoration project for the remaining five years, as the license was granted for 25 years of operation. As of the time of this study, the actual financing did not meet the goal due to waning interests of the company on the carbon trading potential and lack of access to potential investors. As of 2019, a coal company adjacent to the Project D’s site acquired the project as part of their GHG emission offset.

The actual restoration costs may be higher than the estimates because the main actors of both projects benefited from internal and external supports. Project A received supports for revegetation, fire prevention and fire suppression, as well as for monitoring and patrol from their partners (e.g., National Park) and its donors, which are not included in this study. The supports for revegetation mainly came from the non-forestry sectors, which made possible through the MoEF Decree P.50/2016 that urges non-forestry related concessionaires to participate in watershed rehabilitation in non-commercial forests, e.g., National Parks, to offset their negative environmental impacts. Project D received supports from the local university’s community development and research programs funded through a grant. This allowed the company to obtain scientific data and information on their restoration area. The managing coordinator at the university had flexibility on how to engage with the company through the grant and was also employed as the company’s in-house expert. In addition to external or in-kind support, the cost calculations here do not include opportunity costs of alternative land use. If included in the calculation, the costs of restoration would be significantly higher. While the opportunity costs did not necessarily present a tangible cost to the project actors, they represented the enormous socio-economic and political pressure that these restoration projects faced. This point was corroborated in our interviews.

“There are many other companies who want to utilize [the restoration project’s land] for [cultivating] palm oil or mining company who look for [new] mineral sources”. – Operation Manager working for Project D

“It is useless if we talked [or carried out] restoration intensively without involving the external actors [or parties]. When we work alone, other actors may issue mining [concession]...[and] plantation nearby the national park... [or maybe] a factory. [In fact,] permits for palm oil plantations, close to the national park, are still being issued” – National Park Officer working for Project A

However, long-term opportunity costs of alternative land uses may be negative for Indonesia as a whole. GGGI (2015) reported the opportunity costs under the Business as Usual (BAU) economic growth to be nine times lower than those from peatland restoration and conservation-driven green growth. The green growth also generates significantly higher benefits on social development, ecosystems, and GHG emissions.

#### Review of financing and governance alternatives

FAO and UNCCD (2015) proposed the following funding sources and instruments for restoration in forest and landscapes: 1) climate financing instruments, e.g., REDD+, BioCarbon fund, and other climate adaptation fund, 2) development banks and international agencies, e.g., sovereign loan and grant, 3) environmental funds, e.g., Land Degradation Neutrality fund, Congo Basin Forest fund, French Facility for Global Environment, 4) NGOs, e.g., Global Conservation fund managed by Conservation International, 5) national budget and resources, e.g., national schemes for providing public incentives, 6) private sector engagement, e.g., Corporate Social Responsibility funds, and 7) non-traditional or innovative funding, e.g., crowdfunding and green business cards. There are also several other examples of financing ecosystem restoration globally through public funding (Borgström, et al., 2016), city bond (Lucas, 2015), timber sale and potential carbon credit sale (Egan and Seidenberg, 2009), biodiversity offset (Jacob et al., 2017), and many others. We focus on carbon markets in Indonesia by drawing an example from the existing practices in Project C and D.

Public and private investments, and philanthropic grants have been the main source of funding for peatland restoration projects in Central Kalimantan (Table 1). Project A was primarily funded by an international NGO that raised the funding from their organization’s network, including its international chapters and donors. The NGO planned to initiate a trust fund as a platform to facilitate donor supports for restoration at the national park (Project A). Project B funded by the government budget and grants from foreign countries. However, the likelihood of sustaining the efforts of restoration in Project A and Project B may be low due to their dependency on international grants. Projects C and D were funded mainly by private investments, both aimed at eventual carbon trading. Project C holds a restoration ecosystem license (IUPHHK-RE) that allows a concession to utilize Production Forest<sup>9</sup> area through maintaining, protecting, and restoring ecosystem for 60 years. The license was primarily for carbon trading, but they may harvest timber in a sustainable manner. Project D hold the carbon sequestration and storage concession (IUP-PAN/RAP KARBON, categorized under the concession of ecosystem services or IUJL). The business license is valid for 25 years and allows the concession to manage and increase forest productivity for carbon trading.

The challenges described above are likely to persist or intensify under changing climate, causing the increase of frequency of extreme event particularly El-Niño (Cai et al., 2014) that led to long drought. In

<sup>8</sup> Proportion in total gross costs

<sup>9</sup> Government of Indonesia classifies all state forests into three functional groups; these are (1) Conservation Forest with the primary function of conserving plant and wildlife biodiversity, (2) Protection Forest with the primary function of protecting ecosystem services to regulate water, prevent flooding, control erosion, prevent seawater intrusion, and maintain soil fertility, and (3) Production Forest with the primary function of producing forest products (Government of Indonesia’s Law No. 41/1999)

**Table 2**  
Challenges across four different restoration projects (in percentage).

Challenges	Project A (NGO and National Park)	Project B (Government and Int. Dev. Agency)	Project C (Private Company and NGO)	Project D (Private Company and University)	Average % *
Anthropogenic	92	89	100	100	95.3
Ecological	92	47	70	100	77.3
Fire	92	74	70	60	74
Funding	62	32	30	100	56
Institutional	69	42	60	40	52.8
Law enforcement	-	-	20	60	40
Spatial plan	46	26	30	40	35.5
Technical	38	26	-	40	34.7
Human resources	23	26	20	60	32.3
Maintenance	38	5	-	-	21.5
Regulation	8	16	30	20	18.5
Research	-	11	-	20	15.5
Did not know	-	-	10	-	10
No challenge	8	-	-	-	8

-: no or not enough information available

\* indicating average percentage of each challenges reported by the key informants across the projects

2019 dry El-Niño season, the MoEF forest and land fire monitoring system, i.e., Sipongi<sup>10</sup>, reported that burnt area in Indonesia has increased ten-fold (1.65 million ha) from 2017 (0.17 million ha). About 19% of the burnt area in 2019 was located in Central Kalimantan. The increasing impacts of climate change and demand for commercial crops threaten peatland restoration projects as the extent, frequency, risks, and uncertainty of disturbances intensify (Lavendel, 2003). It is reasonable to expect that all projects would incur substantial additional costs, which may be difficult to finance even with additional supports from the donors, partners and other external actors. Secure and diversified long term funding sources are needed to maintain the restoration efforts. In this case, we argued carbon trading from carbon-dense peatland would be the key in financing restoration efforts. Trading ecosystem services, especially carbon credits, is a promising business model due to the growing global pressures on Indonesia, as well as increasing market demands for carbon offsets. About 1,600 companies in 2019 are currently buying or will buy carbon credits to offset their emissions throughout their value chains (World Bank, 2020). With increasing climate awareness, the willingness to pay for emission reductions is high and growing in voluntary carbon markets, with forecasters projecting verified offsets shortages in the near future (Forest Trends' Ecosystem Marketplace, 2020). Although the carbon credit price remains substantially lower than expected, the initiatives on carbon trading are growing considerably with more than 14,500 registered carbon credit projects equal to 4 billion tCO<sub>2</sub>e of cumulative carbon credits (World Bank, 2020).

Ecosystem restoration is one of the priorities in the plan to achieve Indonesia's First Nationally Determined Contribution (NDC) issued in 2016. With the issuance of a moratorium on primary natural forest and peatland in Presidential Instruction No. 5/2019, President Joko Widodo postponed all new licenses on primary natural forest and peatland, except for ecosystem restoration licenses. The Presidential decree also instructed the MoEF to continue its efforts in critical land management through ecosystem restoration, replanting, and recovery. In terms of ecosystem restoration as a business, there were 16 IUPHHK-RE concessions across Indonesia totaling 0.62 million ha with US\$ 37 million investment as of 2018 (MoEF, 2019). Four of the concessions (25%) were located in Central Kalimantan and owned by private companies, including Project C studied here. There were also various IUJL

concessions in Indonesia spanned across 0.05 million ha with \$2.7 million investment, including Project D. The combined number for both IUPHHK-RE and IUJL was still low compared to the number of licenses issued to the timber plantation concessions (IUPHHK-HTI) and timber utilization at natural forest (IUPHHK-HA), which are 295 (total 11.4 million ha) and 254 (total 18.5 million ha) concessions respectively. To achieve Indonesia's ambitious NDC, it will be necessary to promote a hybrid governance model engaging both private and public sectors. Markets for ecosystem services can be supported and expanded by favorable policies that encourage more ecosystem restoration and environmental services-focused businesses.

However, as seen in the case of Project D, developing a long-term restoration project relying solely on private investment may be a risky proposition as their business interests can change quickly depending on market conditions. Private companies and their investors may not tolerate slow development of carbon markets and necessary registrations to secure their investment. Still, the current state of carbon business in Indonesia is dominated by private companies relying on private investments. There are opportunities for public sector to work with private businesses for managing and restoring peatland ecosystem, which would also provide public benefits. The role of public sector, i.e., national and subnational governments, could be leveraged through a hybrid governance such as state-owned enterprise (BUMN), regional government-owned enterprise (BUMD), or village government-owned enterprise (BUMDes). BUMN, for example, have contributed to Indonesia's economy by providing financial support, i.e., dividend to the government as a part of the shareholder, tax, and non-tax revenue. In addition they provide non-financial contributions, i.e., as an agent of development who act as a motor for infrastructure development, financial inclusion, and Micro, Small, and Medium Enterprises (MSMEs) facilitator (Ministry of State-Owned Enterprise/BUMN, 2020). BUMDes, which operates at a more micro level, benefited the community through its programs, reduced unemployment, and advanced entrepreneurship in the case of Klaten Regency (Alfirdausi and Riyanto, 2019). However, benefits may vary across regions in Indonesia. BUMN alone contributed around 2.3 percent of the government revenue in 2017 (Jahja et al., 2020). In 2019, it contributes IDR 469 trillion or approximately USD 32 billion (Ministry of State-Owned Enterprise/BUMN, 2020). BUMD and BUMDes financial contributions' information are limited and available on case by case basis, but their role has been substantial in encouraging community business development (Caya and Rahayu, 2019; Alfirdausi and Riyanto, 2019). These enterprises were regulated under the Government of Indonesia Decree No. 72/2016 and No. 54/2017 and Ministry of Villages, Rural Areas Development and Transmigration No. 4/2015 that allows the government to invest in enterprises that manage

<sup>10</sup> Source: Direktorat Pengendalian Kebakaran Hutan dan Lahan; Direktorat Jenderal Pengendalian Perubahan Iklim, Kementerian Lingkungan Hidup dan Kehutanan. 2021. Karhutla Monitoring System. Available at <http://sipongi.menlhk.go.id/home/main>



**Table 3**  
Challenge scenarios to estimate the cost of restoration with regards to the spatial and temporal and challenges dynamics.

Challenge scenario	Time duration (years)		Degree of severity of the challenges		Impact to the restoration's approach			Reduction/Prevention and Suppression of fire	Impact to the restoration target
	Project A	Project D	Ecological	Social and economic	Rewetting	Revegetation	Revitalization		
1. No Challenge	30	25	NA	NA	NA	NA	NA	NA	NA
2. No Challenge	50	50							
3. Medium Challenge	30	25	One-time occurrence of medium severity fire throughout the project duration	Medium severity social and economic challenges	50% additional costs in canal blocking construction	50% additional costs in replanting	Additional cost (one time) to community development and socialization	Additional cost (one time) for fire suppression and prevention efforts	Delay in peat accumulation (5 years) <sup>*</sup>
4. Medium Challenge	55	55							
5. High Challenge	30	25	Twice of occurrence of high severity fire throughout the project duration	High severity of social and economic challenges	90% additional costs in canal blocking construction	90% additional costs in replanting	Additional cost (twice) to community development and socialization	Additional cost (twice) for fire suppression and prevention efforts	Delay in peat accumulation (15 years) <sup>*</sup>
6. High Challenge	65	65							

\* Delay in peat accumulation was assumed to be in 5-15 years due to the challenge's intensity (e.g. fire) that will damage the facilities and the project needs more time to rebuild the restoration facility and achieve the peat accumulation target. The approximate year of delay come from the calculation considering the level of severity of the challenges.

public assets. Setting up restoration “hubs” in restoration hotspots, such as Central Kalimantan, has been argued as a way to optimize restoration infrastructure and supply chains while reducing fixed costs and improving logistics (Brancalion et al., 2019, 2017; Menz et al., 2013). Public enterprises in these hubs with effective legal and enforcement mechanisms from the government can help avoid some of the pitfalls of market-based solutions that are commonly practiced for sustaining restoration efforts and driving more sustainable livelihood of the communities. Recently the Government of Indonesia established a policy to accelerate investment that encouraged inter-institutions coordination. With the recent MoEF Decree No. P6/2020, the MoEF devolved its authority for issuing licenses to the Indonesian Investment Coordinating Board, which is expected to increase green investment. The legal umbrella could also be a platform for facilitating investments as well as exercising result-based payments and a financing mechanism for nature-based solutions.

**Discussion**

Human activities both for commercial and non-commercial purposes shaped the degraded conditions of peatland ecosystem in Indonesia. The actors who managed restoration projects in Central Kalimantan agreed that Central Kalimantan's peatlands experienced many disturbances due to timber extraction, agricultural conversion, and many more. The body of literature on drivers of degradation is already extensive (Suyanto et al., 2009; Anshari et al., 2010; Dommmain et al., 2016; Hergoualc'h et al., 2017; Dohong et al., 2017). However, little is known about the challenges in assisting recovery of degraded peatlands. Challenges in peatland restoration are argued to be interdependent and mutually reinforcing, thus a ‘narrowly focused solution’ would risk the overall success of the restoration efforts (Harrison et al., 2019). Our study revealed that, despite the similarities in the types of challenges, the degree and intensity are site-specific due to the embedded social and ecological conditions (Table 2). The presence of drainage canals and heavily degraded conditions posed ecological challenges to restoration efforts. The key informants we interviewed also identified that active settlement within the project area and intensive human activities, such as fishing, hunting, illegal logging, and heavy grazing were putting pressures on restoration efforts. These challenges were exacerbated by lack of community acceptance, institutional complexities, overlapping/conflicting interests and lack of capacities, and unclear regulations to support carbon trading progress. Documenting the progress and lessons learned from responding to these challenges would be critical for other proponents to formulate plan, manage the risk, and allocate adequate resources, as well as setting up realistic and measurable goals.

Although the challenges were elaborated during the interviews, additional costs and time to address some of the challenges for meeting the restoration targets were not explicitly acknowledged by the key informants in their planning and management. Generally, restoration projects in Central Kalimantan involved some types of pre-restoration and restoration activities to restore the hydrological functions of peatlands, revegetate peatland, and develop more sustainable alternative livelihood options for their communities. We found that the actors could easily identify the direct costs and specific timeline for the planned activities. However, indirect costs (i.e., transaction costs to address social, economic, and ecological challenges) and time delays due to the challenges were mostly excluded from the total cost calculations and timeline planning. For two projects that provided their financial information for this study, the indirect costs are substantial parts of the total costs of restoration, accounting up to 45% and 34% of the total costs of Project A and D respectively. As addressing higher intensity of challenges would require longer project duration to meet its targets, the time delay subsequently imply higher operational costs. Hence, higher intensity of challenges and longer project duration result in greater total costs.

Indonesia's peatland restoration efforts would require securing long-

**Table 4**  
Total estimated costs and the extent of direct-indirect costs.

Challenges scenario	Timeframe	Direct Cost * (%)	Indirect Cost * (%)	Total Estimated Gross Costs (US\$ 000)	Total Estimated Net Costs** (US\$ 000)	Other/ hidden costs***
<b>Project A</b>						
No	30	0	0	4,986	3,138	Cost for supply and operation cost for revegetation, fire prevention and suppression, monitoring and patrol Opportunity cost for other alternative land uses
No	50	0	0	6,502	3,455	
Medium	30	87	13	5,757	3,536	
Medium	55	85	15	8,072	3,982	
High	30	55	45	9,121	4,886	
High	65	59	41	12,951	5,516	
<b>Project D</b>						
No	25	0	0	24,743	7,825	Cost for community development and research Opportunity cost for other alternative land uses
No	50	0	0	25,857	7,879	
Medium	25	91	9	28,440	8,664	
Medium	55	90	10	30,452	8,750	
High	25	66	34	47,688	11,375	
High	65	66	34	51,266	11,241	

\* percentage proportion of gross costs

\*\* if rate/discount factor were considered

\*\*\* cost bear by other partner or proponents (e.g. donor, the concessionaire holder) in supporting the implementation of restoration project. This also include the opportunity costs for other alternative of land uses of the restoration area. The costs were not quantitatively accounted due to limited availability of the information. Hence, the actual restoration costs may be significantly higher and pose for tangible and intangible consequences.

term commitments and funding. The current presidential administration has committed to extend the peatland moratorium, but restoration businesses have been undervalued compared to other businesses with extractive activities. Green business models have potential to leverage active participations from both private and public sectors and play a critical role in generating benefits for broader communities and assisting the recovery of degraded ecosystem while generating revenue streams. It is also a way to realize Indonesia's NDC. Although the markets for ecosystem services are currently dominated by the private sector, public sector involvement through hybrid governance (BUMN, BUMD, or BUMDes) is feasible due to the presence of the legal umbrella. Investment and operation of these green businesses in rural areas can stimulate local economies while creating local employment opportunities. The revenue can be circulated back to fund programs and activities that generate benefits for the local communities within the jurisdiction. Grants, loans or other types of financing schemes should be directed to establish and match the public-private investments of this kind. However, it is important to note that Indonesia's state-owned enterprises, such as BUMN, have been marked by poor performances (Jahja et al., 2020; Fitriiningrum, 2020) and they have been involved in many corruption cases in the past (Jahja et al., 2020). They also pose potential conflicting socio-political and economic objectives (Fitriiningrum, 2020) and lack capacity to respond external risks, particularly adaptation to the risks of climate change, with the current risks' mitigation system (Isharyanto et al., 2020). Authors have recommended improvement in Indonesia's state-owned enterprise operational efficiency and service delivery, reform of its regulation and governance, improvement of macroeconomic condition, intensive control of performance, and support from the government (Fitriiningrum, 2020; Isharyanto et al., 2020; Khatri and Ikhsan, 2020). With improvement in good corporate governance, it is possible for these types of enterprises to operate with private sector-like structure but managed for generating maximum benefits to the public.

## Conclusions

Peatland restoration projects operate under unique socio-ecological contexts that require distinct strategy and intervention for addressing the site-specific problems. The challenges should be anticipated and their cost implications should be internalized within the project's cost structure. Our study documented the challenges and their cost implications which highlight the needs of continuing commitments and supports from all levels of stakeholders. Transboundary impacts of

peatland restoration substantiates that the benefits outweigh the costs. Enhancing the global carbon pool by restoring the ecosystem functions of peatland as a carbon sink is an efficient way to offset carbon emission for meeting the country's NDC, as well as for improving air quality of the broader region and protecting habitats of critically endangered species. We argue that better understanding of the social and ecological challenges and the costs would allow a broader view in assessing the progress of peatland restoration. The peatland moratorium should be extended or made permanent to create an enabling environment that allows the ecosystem to be restored. Market- or demand-led initiatives are a powerful force to sustain and finance the restoration efforts. Hybrid governance for a green business model, such as restoration ecosystem and ecosystem services enterprises, with active participation from the public sector should be mainstreamed and supported. Additionally, it is crucial to improve and develop ecosystem market regulations to create supportive investment climate and finance peatland restoration over the long term. Options for climate finance should be explored and evaluated for its competitive advantage and feasibility in sustaining and incentivizing restoration efforts. The accounting framework developed in this study can be applied in other projects and should be further revised. Further study is needed to refine the accounting framework and assess the progress and evaluate the effectiveness of restoration interventions in responding to the challenges.

## 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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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.tfp.2021.100131](https://doi.org/10.1016/j.tfp.2021.100131).

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