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Title: Defining peatland restoration in Central Kalimantan, Indonesia

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Abstract (<250):

Indonesia declared an ambitious plan to restore its degraded and fire-prone peatlands, which have been a source of significant greenhouse gas and haze. However, the progress has been slow and the plan cannot succeed without sustained social supports and political will. Although many previous studies argued for the need to see ecological restoration in socio-economic contexts, empirical assessments have been lacking for how restoration is operationalized on the ground. We interviewed 47 key informants involved in four different projects in Central Kalimantan, Indonesia, and assessed their definitions, goals and practices of peatland restoration. Most of the actors we interviewed defined peatland restoration primarily in an ecological context following the global concept of ecological restoration. However, all four restoration projects were designed without determining reference and trajectory conditions. Their intermediate goals and practices were more focused on engaging local communities and developing sustainable livelihood options than improving the ecological conditions of peatlands. To be internally consistent, peatland restoration needs to recognize a social dimension in its process, as well as in its goal. Setting clear trajectory conditions is also important to clarify achievable goals and measurable intermediate outcomes. We propose the following definition of peatland restoration: a process of assisting the recovery of degraded peatland ecosystem to achieve the appropriate trajectories defined through multi-stakeholder collaboration within social-ecological contexts. We hope to generate healthy debates to further refine the definition that encompasses both social and ecological dimensions to generate broader support for sustaining and expanding peatland restoration projects in Indonesia.

Key words: peatland, tropical developing country, peatland restoration, ecological restoration, Indonesia.

Conceptual Implications (<120):

- This study provides on-the-ground evidence for the need to see ecological restoration in socio-economic contexts.
- We propose a definition of peatland restoration in Indonesia with acknowledgements of complexities and uncertainty of restoring severely damaged ecosystem under developmental pressure and climate change.
- Peatland restoration is a process of assisting the recovery of degraded peatland ecosystem to achieve the appropriate trajectories defined through multi-stakeholder collaboration within social-ecological contexts.
- To accomplish its ambitious plan, Indonesian government should define reference and trajectory conditions for peatland restoration to clarify achievable goals and measurable intermediate outcomes.
- The new definition can help develop feasible and practical guidelines for restoring Indonesia's peatlands within its social-ecological context.

INTRODUCTION

The peatland ecosystem is the world's largest terrestrial carbon pool and long-term carbon sink that contains 550 Gigatons (Gt) of carbon (Joosten&Couwenberg 2008, Barthelmess et al. 2015). Peatlands in tropics hold more carbon per hectare (10 times compared to mineral soil) than peatlands in boreal (7 times) and subpolar (3.5 times) systems (Joosten&Couwenberg 2008). Indonesia holds the second largest tropical peatlands in the world (22.5 million ha) holding 28.1 Gt of carbon, next to Brazil (31 million ha) (Gumbricht et al. 2017, Warren et al. 2017). Indonesia's peatlands have undergone extensive disturbances due to illegal mining (Dommain et al. 2016), overfishing (Hergoualc'h et al. 2017), and illegal and legal logging (Suyanto et al. 2009, Anshari et al. 2010, Dommain et al. 2016, Hergoualc'h et al. 2017). Some of these activities for subsistence can be traced back many decades (Medrilzam et al. 2014, Meijaard et al. 2013). More recently, rapid expansion of commercial agriculture and industrial plantations created intense pressures on Indonesia's peatlands (Page et al. 2011). Draining and clearing peatlands cause peat to dry out and become more susceptible to fire (Turetsky et al. 2015, Osaki et al. 2016, Miettinen et al. 2016). After the severe fire season in 2015 emitting 1.5 billion mtCO (Field et al. 2016), the Indonesian government established the Peatland Restoration Agency and declared the ambitious plan of restoring two million hectares of degraded peatlands within five years by 2020 (Presidential Decree 2016). Although several peatland restoration projects have been initiated and moving forward, the plan is severely underfunded (Hansson& Dargusch, 2018) and has only achieved 5 percent of the target as of 2018 (Jong 2018).

Restoration projects in tropical ecosystems, such as peatlands, operate under ill-defined property rights, weak governance, and low economic development (Putz& Redford 2010, Phelps et al. 2010, Larson 2011). International pressure and external financial supports that initiated the projects are often insufficient to sustain the efforts. For Indonesia's ambitious plan to succeed, it is essential to create an internally consistent shared vision for peatland restoration among populations with diverse values. One of the major barriers for creating the shared vision is the lack of a clear definition of peatland restoration (*restorasi*). The term is often used interchangeably with other terminologies even in the Ministerial regulations, such as rehabilitation (*rehabilitasi*) and reclamation (*reklamasi*). Unlike restoration, rehabilitation is the process of restoring ecosystem functionality without regards to the recovery of native biota in an appropriate native reference ecosystem (McDonald et al. 2016a; Gann et al. 2019). Reclamation

is returning and stabilizing the land to assure public safety and improve the aesthetic for a useful purpose (SER 2002, 2004). The different terms used create confusion among restoration proponents and practitioners as to what their goals should be and how to design and implement projects at the local level and monitor their progress.

Another barrier is lack of consideration for social dimensions in defining restoration. Indonesia estimates that 13.5% (16.31 million) of the total population eligible for the state's poverty assistance benefit resides within and around forest areas, including peatlands (Badan Pusat Statistik 2018). Forest and peatland restoration efforts in Indonesia cannot be successful without addressing the livelihood needs of the marginalized populations. Another need to incorporate social dimension arises from the uncertainty of what can be restored. Past anthropogenic disturbances involved draining water out of peatlands by means of drainage canals, which dried out peat and affected the hydrological dynamics of the whole landscape (Andariesse 1998, Huat et al. 2014, Joosten et al. 2016). The disturbances in water balance can alter the peat to become resistant to rewetting and susceptible to fires indefinitely, perhaps permanently (Turetsky et al. 2015). With worsening effects of climate change and increasing anthropogenic pressures for land use change, restoring pre-disturbance conditions may not be possible. Peatland restoration projects should be able to provide supporting conditions for fire prevention, as well as peat initiation and accumulation (Page et al. 2004). Thus, what constitutes a properly functioning ecosystem and the types of trajectories that would characterize the recovery of degraded ecosystems has to be defined within the socioeconomic and political contexts, as well as the ecological one (Temperton 2007).

Globally, peatland restoration would be considered as a type of 'ecological restoration', which is often defined without explicit consideration of social dimensions. For example, some of the most widely accepted definitions, such as one by the Society for Ecological Restoration (SER 2004) and the United Nations Convention on Biological Diversity (CBD 2016), defined ecological restoration as the "process of assisting the recovery of a degraded, damaged or destroyed ecosystem." While the definition helps us understand what ecological restoration does, it lacks social dimensions for clarifying why we should care (Martin 2017). Other definitions added a point on human well-being such as stating that restoration is "to fulfill society's needs" (UN Environment 2019) and to restore "vital ecological and social functions" (GPFLR 2018).

Although social dimensions were addressed as part of the restoration goals in these definitions, they were not acknowledged for their role throughout the process of restoring an ecosystem.

Many have argued over the years for the need to see restoration in much larger, expanded socio-economic contexts and redefine ecological restoration by including human and social dimensions (Clewell& Aronson 2006, Gosnell& Kelly 2010, Higgs 1997, Higgs et al. 2014, Kim& Hjerpe 2011, Hallett et al. 2013, Shackelford et al. 2013, Suding et al. 2015, Martin 2017, Temperton 2007, Swart et al. 2018). However, there is lack of assessments for how the definition is operationalized and linked to goal setting in on-the-ground restoration (Hallett et al. 2013). An ecosystem is comprised of "interacting, cross-scaled, coupled systems" (Swart et al. 2018) with increasing human impacts and pressures (Temperton 2007, Swart et al. 2018, Wiens&Hobbs 2015). Thus, ecological restoration should be redefined as social-ecological restoration with broader views accommodating: 1) the cultural and social aspects reflecting interests and concerns of a diverse population; 2) the objective to generate a healthier relationship between people and the ecosystem; 3) emphasis on the relationships among science, human, and nature (Higgs 1997, Temperton 2007, Gosnell&Kelly 2010, Martin 2017). Higgs et al. (2014) proposed a new generation of restoration projects (Restoration v2.0) to acknowledge the complexity of ecological processes and multiple trajectories, while recognizing the need for a pragmatic approach for addressing human livelihood and cultural needs.

To incorporate these broader views to focus on restoring social-ecological systems, the global concept of restoration should be redefined and practiced within the social, economic and political contexts of the restoration location. The proposed process of this translation is shown in Figure 1.

<Figure 1>

International principles and standards of ecological restoration have been identified by the Society for Ecological Restoration (2004, 2nd edition in Gann et al. 2019), which can serve as the starting point for Indonesia to define peatland restoration. One of the key principles defining ecological restoration is having a predetermined reference ecosystem for guiding activities of restoring ecosystems. The reference ecosystem helps identify native and non-native (exotic) species, as well as any missing ecological community group or ecological function. It is the

model or benchmark of restoration representing non-degraded ecosystem for planning and evaluating projects (SER 2004, McDonald et al. 2016b). Ecosystems are dynamic and multi-layered, thus reference conditions are more "tapestries of multiple and successive states", rather than a single snapshot frozen in time (Balaguer et al. 2014). Trajectory condition is "a course or pathway of recovery or adaptation of an ecosystem over time" (McDonald et al. 2016b), and a "developmental pathway" towards desired ecosystem (SER 2004). Building a sustainable and resilient ecosystem is the main focus of many restoration projects, especially in the face of climate change. It is important not only to understand the ecosystem functions in the past, but also desired state in the future (Suding et al. 2015) by embracing the dynamics within ecosystem, especially the potential of native species and communities to recover, reassemble, adapt and evolve (Gann et al. 2019). The attributes of ecological restoration, as well as international principles and standards help set specific goals and evaluation parameters to provide important metrics of success for restored ecosystem. Location-specific contexts, such as land use history and biophysical conditions, as well as fine-scale reference conditions, should factor into operationalizing ecological restoration at the landscape level. We applied this framework in Figure 1 to assess four peatland restoration projects in Central Kalimantan.

The research questions are: 1) how do current proponents and practitioners of peatland restoration define restoration?; 2) how were the restoration goals articulated and translated into practice? Based on the findings, we propose a new definition of peatland restoration, which is meant to serve as a starting point for public discourse to create a shared vision for peatland restoration in Indonesia.

METHODS

Study Area

One third of peatlands in Indonesia is located in the western and south-central regions of Kalimantan island (32%) with thickness ranging from shallow (50-100 cm) to very deep (more than 400 cm) (Osaki et al. 2016) (See Figure 2). Central Kalimantan Province is a home to one of the largest contiguous peatland areas in the world and the third largest in terms of its total land size and size of peatlands in Indonesia (Warren et al. 2017). Construction of drainage and irrigation channels, which peaked with the 1996 mega-rice project, degraded most of the peatlands in Central Kalimantan (Joosten et al. 2016). The mega rice project to convert peatlands

into rice field created more than 4,000km of drainage and irrigation channels in central Kalimantan from 1996-1998 (Boehm& Siegert, 2001). While degraded peatlands created subsidence and greater fire frequency, drainage and canals also improved access to previously inaccessible interior parts of forests and peatlands, for further disturbances, such as legal and illegal logging and land clearing (Boehm& Siegert, 2001).

<Figure 2>

There are several ongoing peatland restoration projects involving different actors in Central Kalimantan. We selected the four largest peatland restoration projects managed by different entities and assessed: 1) a national park partnered with a non-governmental organization (NGO) (hereafter referred as project A), 2) a government agency partnered with a NGO (hereafter referred as project B), 3) a private company partnered with a NGO (hereafter referred as project C), and 4) a private company partnered with an university (hereafter referred as project D) (See Figure 2 for the study area location and Table 1 for the project details). Although the drivers of peatland degradation are similar for all four projects sites, these four projects show a range of different restoration proponents in Indonesia from public agencies to private companies pursuing for-profit motives though carbon trading. They cover more than 1 million ha of peatlands across six districts in Central Kalimantan Province, Indonesia.

<Table 1>

Data Collection

We employed semi-structured interviews to assess shared understanding among the main actors working on peatland restoration projects in Central Kalimantan. The selection of interviewees was based on their familiarity with peatland restoration following the purposive sampling methodology (Teddlie & Tashakkori 2009). Our questions focused on the restoration projects and management, so the key informants were limited to those who held formal positions in restoration organizations with relevant knowledge and were willing to participate. Using the research questions as the guideline, we conducted interviews until the saturation point was reached. The saturation point is when there are no new insights gained by additional interviews

(Glaser & Strauss 1967) and the collected data has met the needs to address research questions without stretching too widely and affecting the coherence (Saunders et al. 2017).

Data collection was being carried out in 2017. We interviewed 47 key informants from 20 different institutions totaling 39 hours of interviews. The informants were from restoration and community forums (23%), a national park management (17%), NGOs (17%), private concessions (17%), local governments (13%), a national government agency (9%), a forest management unit (2%), and one university (2%). We asked open-ended questions to allow the respondents to elaborate on their responses and identify additional issues, which would not be possible in a closed ended question format (Jamshed 2014, O'Cathain & Thomas 2004). Audio-recorded interviews were transcribed using F5 Transcription PRO (Haselberger 2018). We constructed codebooks to define themes and sub-themes with example of response emerged in interviews (Lavrakas 2008). It is used to guide a coherent coding process. In an attempt to allow for new themes to emerge, the final codebooks were developed as well (Blair 2015). Using the codebooks as a guidance, themes and sub-themes within the data were identified then coded or grouped using NVivo for Mac version 11.4.2 (QSR International Pty Ltd 2017). The questions and the data collection procedure were reviewed and approved by the Internal Review Board for human subject research at the authors' home institution.

RESULTS

Definitions of Peatland Restoration

The majority of actors we interviewed defined peatland restoration primarily in ecological contexts (92-100%) (Table 2). The presence of drainage canals was commonly identified as the main driver of peatland degradation. The restoration projects were designed to block these canals to bring the waterlogged condition back before revegetating the peatlands. Although restoration was defined as the process of bringing back former, presumably natural, ecosystems, it was acknowledged that irreversible damage may have occurred.

<Table 2>

Some offered a more pragmatic definition of restoration as a process of improving ecological conditions, preventing further degradation and protecting the existing good peatlands from fires.

> "Restoration? [it's] restoring to its former condition [prior to the disturbance]. Well, we know there won't be, we would never achieve precise former [peat] condition. But, it's the only way to protect the peatland from further degradation." – forest manager working for Project A.

> "Definition of restoration, restoration—what we expected—is the locations [area or peat forest] would return to the former [condition]. Restoring. But, we hope that it would be—at least—equal to [the characteristics of] secondary forest, comparable to the secondary forest [in general]" - university lecturer working for Project D.

Although a minority (8-32%), some respondents acknowledged that social contexts cannot be ignored when defining peatland restoration. Social aspects were highlighted by more respondents (32%) working on the government-led project (Project B), although they tended to be narrowly focused on generating direct benefits to communities, such as the increased water level being useful in preventing fires, and revegetation with commercial crops.

> "We restore the peat to be beneficial [peat]lands…we replant the [peat] forest with crops like rubber [*Hevea braziliensis*] that is potential to improve the community's welfare. If we improve the community welfare, the [peatland] area would be maintained." – forest manager working for Project B.

Some respondents emphasized restoration in a more holistic sense, e.g., the needs of 'restoring' native ecosystem with native tree species that existed previously in peatlands and building community understanding to increase their participation, which highlighted diverse values among restoration actors and local communities.

> "[Restoration] is restoring [peat] its functions, but, accompanied by understanding the level of community support [who lived] nearby. When there were no supports from the community, [restoration] is non-sense, regardless of costs incurred, supports, [and] policies…how the [community] engage, the knowledge transfer, [those are] all that matters on restoration." -NGO officer working for Project A.

Goals of Peatland Restoration

Peatland restoration is a long-term process beyond the planning horizons of the projects. We defined ultimate goals as the end outcomes of peatland restoration that the restoration actors hoped to achieve in the long run. Achieving these goals may be beyond the control of the project actors as they are affected by climate change and other global forces (Lavendel 2003). Intermediate goals are those that the project actors can reasonably expect to accomplish within the project duration. We examined ultimate and intermediate goals established by the project actors for their project areas (Table 3).

<Table 3>

The majority of the respondents in all projects identified both ecological and social goals as their ultimate goals, such as restoring ecological/hydrologic functions of peatlands and enhancing community welfare and promoting their participations in restoration projects. Although all respondents from Projects C and D defined restoration primarily in ecological contexts, some identified their ultimate goals, not as restoring ecological conditions, but as carbon trading and reducing greenhouse gas (GHG) emission. This is understandable as these projects were initiated by private companies with carbon trading goals. Only in project A initiated in a national park, did all respondents identify ecological goals as the ultimate goals.

Some of the intermediate goals common in all projects were completion of physical restoration facilities such as canal blocking to increase the water level in peatland areas and prevent the recurring peat fires. Activities related to physical construction of facilities and fire prevention were two most important and realistic intermediate goals that would allow the peat forest to recover or naturally regenerate. However, most of the respondents agreed that just focusing on recovering biophysical properties of peatlands is not enough for restoration projects to succeed in Central Kalimantan. Building human capital and engaging communities towards peatland restoration were identified as critical intermediate goals across all projects.

Although all projects identified engaging local communities and gaining their supports as their intermediate goals, their specific goals vary by projects as participating actors and funders differ. For example, Project A is a partnership between national park agency and NGO focusing on wildlife conservation. Their goals include returning the key species to their original habitats. Frequently stated key species were '*orangutan'* (*Pongo pigmaeus*), which is a species of

critically endangered great apes, and '*ramin'* (*Gonystylus bancanus*), which is vulnerable hardwood species, and both are native to Indonesia (IUCN 2016). For the government led-project, actors working on Project B saw restoration as a potential means for meeting Indonesia's commitment to reduce GHG emissions. For private companies, such as Projects C and D, specific immediate goals include accomplishing annual work plans for the board of management and investors.

Innovations in Practices

Based on literature (Kimball et al. 2015, Dohong 2016), we grouped restoration activities into two groups: pre- and main restoration. The pre-restoration activities, such as research and public consultation or socialization/campaign, would take place before restoration project implementation. The main restoration activities are those for: 1) rewetting dried peatland, 2) revegetation or replanting trees, and 3) revitalizing existing livelihood options or developing more sustainable alternatives. All projects we studied included activities to increase community participation and engagement. The focus was on helping community members understand the importance of peatland restoration, and the needs to reduce the anthropogenic pressure and human-caused fires on the peatlands. Increasing community engagement was identified as part of the exit strategy to maintain the restoration for the long run. Examples of the socialization/education activities were identifying and promoting alternative livelihood options that do not involve draining the peatland and land preparation techniques without using fire. While most of the approaches were relatively similar from one project to another, each project had a unique strategy formulated specifically for addressing the challenges they faced (Table 3). The main innovations are mostly to tackle social issues.

While the emphasis of Project A is on the ecological realm, especially biodiversity conservation on a national park, their innovations are primarily for addressing the social challenges. They created innovative programs, such as tree adoption, canal blocking adoption (in planning), and a trust fund, to encourage community participation. Tree adoption was a part of revegetation efforts to increase local community involvement in monitoring and maintaining planted trees. They selected the species that can be beneficial for the community without being logged. For example, *'jelutung'* (*Dyera polyphylla*) produces resin, which local community can collect and sell without cutting the trees. The idea behind tree adoption is to encourage local communities to recognize the responsibility for looking after growth of the plants, rather than

perceiving the tree planting work as a one-time contract work. The responders working on Project A stated that having the tree adoption program helped achieve more efficient revegetation and increased the community's sense of responsibility. They also plan to initiate the similar approach for canal blocking. To sustain their restoration efforts beyond the project duration, Project A established a trust fund to overcome funding constraints and build more flexibility in budgeting and more sustainable financing.

In Project B, the main actor is the national government agency, Peatland Restoration Agency, leading Indonesia's peatland restoration. Their definition of peatland restoration also emphasized the ecological dimension more than the social dimension. However, their articulated goals and practices underlined social dimensions for building legal security and guidelines to ensure community voluntary-participations in the long run. They developed an indicative map of restoration and brought together relevant laws and technical guidelines as Indonesia's peatland restoration standards. They include guidelines on '*desa peduli gambut*' (peat care village), rewetting infrastructure, revegetation, socialization/ campaign, water level monitoring, and building a social safety framework, as well as relevant village's regulations and laws. The actors in Project B formed many types of community groups or forums, i.e., Forum Hapakat Lestari, *'desa peduli gambut'* (peat care villages) and *'masyarakat peduli tabat (MPT)'* (canal blocking care community). These community-based groups work at different spatial scales (district and village level) and as a platform to discuss and implement the plans and activities. They also facilitated young/ junior researchers to conduct research in order to generate fresh ideas for the future of peatland restoration. Although the goal is to facilitate academic research in at least 1,000 villages, the funding of the young researchers' project is yet to be specified.

The respondents working on Project C also defined restoration mostly in the ecological dimension but emphasized social aspects in their goal-setting and implementation. Project C activities include several innovative approaches to address anthropogenic pressures from local communities. For example, they developed sustainable livelihood options with communities bottom-up. The community members and project managers went through a baseline study together to assess current social and economic conditions of the communities then determined their work plan based on the discussions. The project managers assisted the communities to formulate and implement various programs, such as microfinancing and coconut sugar production. Each community and project managers developed an agreement based on the

community's interests, which specified various programs to be implemented. They targeted illegal loggers, low-income and unemployed community members to participate in their programs. The project also initiated an agroecology school for farmers to operationalize ecological principles into farming practices. The agroecology school initially targeted 18 farmers from two districts with focus on knowledge transfer on techniques for land clearing without using fires and controlling weed without using herbicides. The curriculum included climate changes and building adaptive communities.

Project D shared similar views with other restoration projects in defining the restoration. A significant proportion of their goals (40% in Table 2) was to address social dimensions. Their practices were primarily designed to transfer knowledge and empower people. The project partnered with a local university to encourage college students to study degraded peatland ecosystem under the "Living Classroom" program. This program enabled the students to apply lessons they learned in classrooms to on-ground practices. Under the partnership, the local university lecturers and students conducted routine field visits to the restoration concession area. The students directly participated in the research and restoration efforts, such as biodiversity inventory, camera trap, and assisting community programs.

DISCUSSION

We have assessed four on-going peatland restoration projects in Central Kalimantan to understand how restoration proponents and managers define the concept of ecological restoration and connect their goal setting to practices. We have summarized our major findings and their implications below.

Need for determining reference and trajectory conditions.

Most respondents we interviewed defined peatland restoration primarily in an ecological context, restoring ecological/hydrological functions of peatlands to the *"conditions prior to the disturbances."* However, the respondents also acknowledged multiple disturbances have occurred in the peatland ecosystem over many decades and they do not have clear understanding of what the reference condition should be. As found in government policy documents, respondents used the term, restoration (*restorasi),* interchangeably with other terms, such as rehabilitation (*rehabilitasi*) and reclamation (*reklamasi*). Ecological restoration emphasizes re-establishing a reference ecosystem condition with respect to its species composition and

344 community structure, unlike in rehabilitation and reclamation (SER 2004). For peatland
345 restoration to be ecological restoration, it is important to define one or more reference
346 ecosystems for planning purposes to design trajectory for restoration projects. A simple
347 comparison of pre- and post-disturbance would unlikely to meet the needs to build resilient,
348 desired ecosystem (Balaguer et al. 2014). A selected reference condition, therefore, may reflect
349 one among many potential states within the historic range of a certain ecosystem and may reflect
350 a combination of stochastic events during the development of the ecosystem (SER 2002, 2004,
351 Balaguer et al. 2014). SER (2002, 2004) argued that projects can be categorized as restorative if
352 the activities serve to improve environmental conditions of an ecosystem—with values and
353 principles inspired by ecological restoration—and move to broaden ecological recovery of the
354 system.
355 Peatland-specific regulation, i.e. Government Ordinance No. 71 Year 2014 and No. 57
356 Year 2016 and MoEF Decree No. 16/2017, affirmed that the goal of restoration is to return the
357 nature and functions of peatland ecosystem through natural succession, hydrology restoration,
358 vegetation rehabilitation or other appropriate methods. While these regulations describe the
359 methods, it does not specify the reference and trajectory conditions for goal-setting and program
360 monitoring and evaluation. In other parts of the world, the point of major anthropogenic
361 disturbances was used to set the reference condition. For example, in the dry-conifer forests of
362 the western United States, the forest condition before major disruptions associated with 19th
363 century Euro-American settlement is widely considered as the reference condition (Abella et al.
364 2007). While the recent land use changes for commercial agriculture and industrial plantation
365 since the 1970s can serve as the point of major anthropogenic disturbances in Indonesia's
366 peatlands, it is hard to characterize the prior ecological conditions. Defining trajectory conditions
367 for peatlands in Indonesia is also challenging due to acute development pressures and climate
368 change. Without developing alternative livelihood options, land use conversion will continue.
369 Previous attempts to curb land use change, such as the logging moratorium policy, have not been
370 effective to reduce forest conversion because monoculture plantation is too lucrative for private
371 companies and smallholders to give up the practices (Suwarno et al. 2015). Thus, determining
372 trajectory conditions will have to consider the feasibility of the pathways to peatland restoration
373 that can generate political will and multi-stakeholder participation in the long run. Our results
374 confirmed that there is no clear or shared understanding of the reference and trajectory

conditions among the restoration actors that we interviewed. There is an urgent need to define an appropriate native reference ecosystem and native biota. Without a clear reference condition, it would be hard for the current efforts to move beyond rehabilitation (SER 2004).

Peatland restoration as social endeavors

While the previous definitions of ecological restoration primarily embraced ecological fidelity (SER 2004, UN CBD 2016), current scientific and social trends require redefining ecological restoration (Gosnell& Kelly 2010, Higgs et al. 2014, Martin 2017). Our results show that while only some actors recognized social dimensions in defining restoration on Indonesia's peatlands, most of them emphasized local community engagement in their goals and practices. The respondents emphasized the importance of understanding and securing support from local communities to increase voluntary participation in reducing anthropogenic pressure. All four projects incorporated both ecological and social aspects in their ultimate and intermediate goals. They are expected to increase community awareness for ecological and cultural importance of peatlands by involving local communities in passive and active restoration. In active restoration, the community members are employed as paid-workers (full time and part time) to plant trees and construct restoration facilities. Passive restoration is stopping anthropogenic activities as restoration efforts. The interview results confirmed the prevalence of anthropogenic activities, such as fishing, hunting, illegal logging, illegal settlement, and grazing within and nearby restoration area. Canal blocking, which is a restorative activity, can be destroyed after construction not only because blocked canals might inhibit local community's livelihood activities, but also because the community members do not understand their purpose. To overcome these challenges, the project actors are trying to share their knowledge and technology to change community perception and practices. They assist communities to improve their land clearing techniques and seek sustainable alternative livelihood options. These strategies to recognize social demands in the restoration approach can reduce the pressures from anthropogenic activities. Recognizing the social dimension within restoration enabled the restoration actors in Central Kalimantan to have broader multiple goals and objectives, as suggested by Martin (2017). It can also help define more clear roles and responsibilities with the communities.

Setting measurable goals for peatland restoration

For the intermediate goals, actors we interviewed identified both ecological and social goals, such as preventing recurring fires, constructing infrastructure, maintaining the forest and achieving target as planned in their annual work plans. These goals primarily focused on setting reasonable targets that can be accomplished within short term or during the project duration. However, they also acknowledged uncertainties regarding the time frame to accomplish restored peatlands and even expressed their pessimism. Once exposed to intensive drying and the sun, peat resists rewetting (Page et al. 2004). Damages occurred in peatlands may be irreversible and restoration efforts may not be able to generate 'pristine' peatland conditions (Andariesse 1988, Huat et al. 2014). However, all projects we studied focused on implementing rewetting treatments without long term assessments of their effectiveness. Even if the restoration treatments do not restore degraded peatlands, they may assist the process of creating favorable condition to allow for organic materials to accumulate and form new peat. However, peat accumulation and formation processes, which depend on particular environmental conditions, may take over 2,500 years to accumulate 3.5 meters of peat (Page et al. 2004). Obliged to identify measurable targets, the actors established reasonable and measurable goals to achieve within the duration of a project, such as the numbers of canal blocking facilities built, numbers of villages assisted, and hectares of trees replanted. However, we found that they do not have specific ideas about how to link these intermediate goals to long-term effectiveness of restoration project. To meet its national commitment to restore peatlands, it is important for the Indonesian government to develop consistent guidelines for monitoring and reporting the progress of peatland restoration by linking intermediate and ultimate goals.

Innovations in practices

Despite of the different ecological, socio-economic and political complexities that they face, the project actors translated their concepts and goals into similar main activities: rewetting, revegetation, and revitalization of livelihood. They formulated distinct approaches to address specific challenges that they faced. Some of the breakthroughs are tree adoption, farmers' school in agroecology, trust fund, young researcher fellowship, and living (outdoor) classroom. Most of these innovations are designed to address social aspects, especially fostering knowledge transfer for sustainable peatland management as well as encouraging broader participation from the communities, academic researchers, and other related parties, such as NGOs, government agencies and private companies. These practices of community engagement address several key

social goals that have been discussed in literature as critical for restoration success, such as reconnecting communities with nature (Shackelford et al. 2013), and increasing public awareness for benefits of healthy ecosystem, thus importance of restoring degraded ecosystem (Suding et al. 2015) as well as their role in goal-setting (Shackelford et al. 2013). We found that these innovations are crucial investments to reduce anthropogenic pressures and help ensure that the restoration efforts can be sustained in the long run. These earlier lessons should be shared broadly to promote peatland restoration in Indonesia.

Definition of Peatland Restoration in Indonesia

Incorporating human dimensions in defining and practicing ecological restoration has been advocated before (e.g. Shackelford et al. 2013, Higgs et al. 2014, Suding et al. 2015, Martin 2017). Many projects reported in the Global Restoration Network (GRN) include some social values in their goals, such as education, economic benefits, community engagement. governance and cultural values (Hallett et al. 2013). In response to the growing recognition for human elements of ecological restoration, the recent revisions of international standards and principles accommodated social aspects and emphasized public engagement (McDonald et al. 2016; Gann et al. 2019). However, ecological restoration is yet to be redefined despite of the growing body of literatures arguing for redefinition (e.g. Higgs et al. 2014; Martin 2017).

Based on the on-the-ground experiences from peatland restoration projects in Central Kalimantan, we propose the following definition for peatland restoration in Indonesia: a process of assisting the recovery of degraded peatland ecosystems to achieve the appropriate trajectories that are defined through multi-stakeholder collaboration within social-ecological contexts. This new definition acknowledges social dimension in the process of restoration, as well as its goals and also recognizes the importance of collaborative process in setting ecological desirable and socially feasible trajectory conditions. The proposed definition is meant to be a starting point for academic and public discourse to create a shared vision for peatland restoration in Indonesia. More research based on long-term monitoring is needed to 1) develop potential trajectory conditions that promote the resilience of peat ecosystems; 2) link intermediate goals to long-term effectiveness of restoration projects; and 3) promote better understanding of socio-ecological system encompassing peatland systems and drivers of changes.

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TABLE 1. Study area, consisting of four peatland restoration projects in Central Kalimantan, Indonesia.

	Project A	Project B	Project C	Project D
Main actor	NGO	National government agency	Private sector	Private sector
Supporting actor	National park	NGO	NGO	University
Project Area	568,700 ha	607,969 ha	149,800 ha	25,000 ha
Land Class	Forest estate.	Forest estate; non-forest estate.	Forest estate.	Forest estate.
Project Duration (planned)	30 years.	5 years.	60 years.	25 years.
Number of Respondents	13	19	10	5

***** Under the Indonesian Agrarian Law (Law No. 5 of 1960) and Forestry Law (Law No. 41 of 1999), all land in Indonesia is classified as either 'forest estate' (*Kawasan Hutan*) or 'non-forest estate' (*Area Penggunaan Lain*). Forest estate belongs to the government and can be allocated to private concessions for specific uses. For Projects C and D, Ecosystem Restoration Concession licenses were issued to the companies. Non-forest estate land is managed by provincial government and can be converted into private ownership as well as used for non-forestry purposes.

Table 2. Definition of peatland restoration based on the respondents' perspective: percentage of respondents that stated some aspects of ecological and social dimensions.

Definition of Peatland Restoration	Project A (NGO and National Park)	Project B (Government and NGO)	Project C (Private company and NGO)	Project D (Private company and university)
Ecological	92%	95%	100%	100%
dimension	8%	32%	10%	20%
Social dimension	8%	-	-	-
Did not know				

Table 3. Ultimate and intermediate goals of peatland restoration: percentage of respondents that stated those goals.

Goals of Peatland Restoration	Project A (NGO & National Park)	Project B (Government & NGO)	Project C (Private company & NGO)	Project D (Private company & university)
Ultimate goals (findings from the interviews)				
Ecological goals	100%	79%	60%	60%
Social goals	38%	58%	70%	40%
Protection from threats	15%	-	-	-
Lesson learned for others	8%	-	-	-
Carbon trading	-	-	10%	40%
Reducing GHG emission	-	11%	20%	-
Intermediate goals (findings from the interviews)				
Ecological goals	46%	16%	10%	40%
Social goals	15%	42%	10%	60%
Fire prevention	15%	32%	10%	60%
Infrastructure for restoration	31%	47%	-	60%
Planning	15%	-	-	-
Research	8%	-	-	-
Funding	15%	-	-	-
Stopping further degradation	-	-	-	20%
Achieving target as planned	-	11%	20%	-
Creating best management practices	-	5%	-	-
Law enforcement	-	5%	-	-
Mainstreaming restoration	-	11%	-	-
Reducing GHG emission	-	5%	-	-
Reducing threats	-	-	10%	-
Promoting other benefits of peat	-	-	10%	-
Institutionalization	-	5%	-	-
Did not know				

- : no or not enough information available

Table 4. Pre-restoration and main restoration activities in restoring degraded tropical peatlands of Central Kalimantan, Indonesia

Peatland Restoration Activities	Project A (NGO and National Park)	Project B (Government and NGO)	Project C (Private company and NGO)	Project D (Private company and university)
Pre-Restoration Activity (derived from the interviews)				
Mapping	√	√	√	√
Survey	√	√	√	√
Obtaining permit/ business license	-	-	√	√
Agreement	√	√	√	√
Planning	√	√	√	√
Socialization/ campaign	√	√	√	√
Research	√	√	√	√
Main Restoration Activity (derived from the interviews)				
Rewetting	√	√	√	√
Revegetation	√	√	√	√
-Trees adoption	√	-	-	-
Revitalization of livelihood	√	√	√	√
Monitoring and patrol	√	√	√	√
Research	√	√	√	√
-Young researchers program	-	√	-	-
-Living classroom	-	-	-	√
Socialization/ campaign	√	√	√	√
-Agroecology school	-	-	√	-
Advocacy to government	-	√	√	√
Supporting infrastructure	√	-	-	√
Fire prevention	√	√	√	√
Planning	√	√	√	√
Forming community group	√	√	√	√
Initiating trust fund	√	-	-	-

- : no or not enough information available

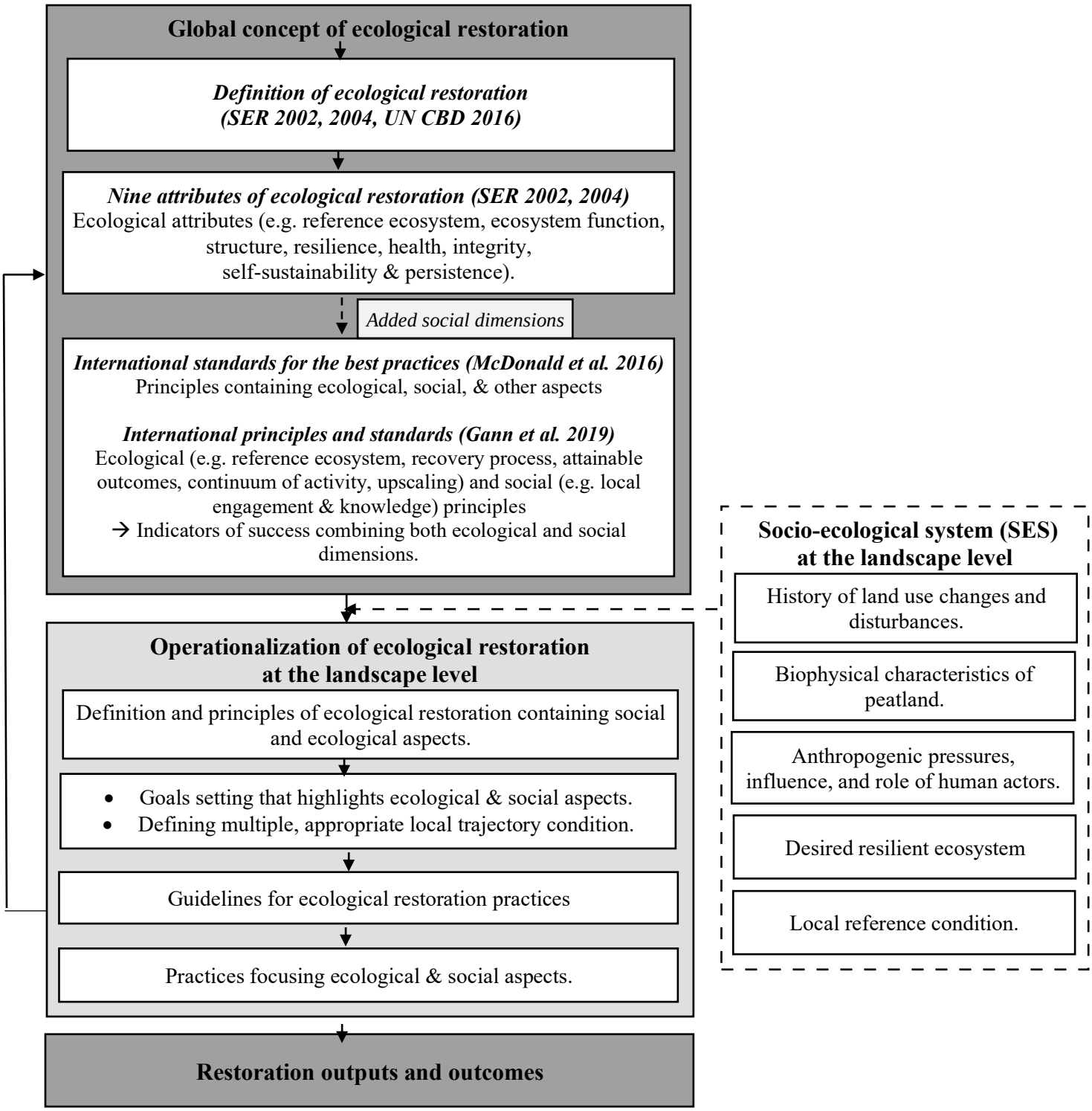

Figure 1. The process of translating and operationalizing ecological restoration into a project at the landscape level. The current definition primarily focuses on ecological fidelity and insufficiently accommodates social dimension. The project goal setting and planning should consider the key elements of the socio-ecological system (SES) at the landscape level. Redefining ecological restoration within the given SES is important to determine achievable intermediate and long-term restoration goals.

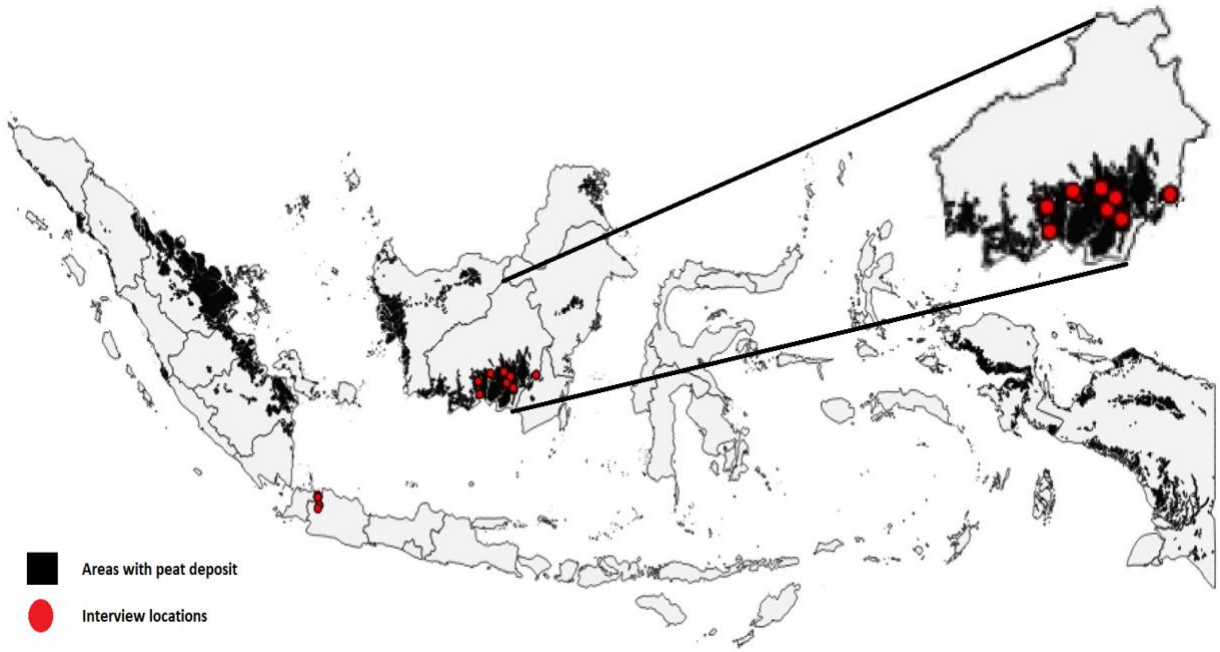

Figure 2 Map of Indonesia's tropical peatland (Scale 1: 16,000,000). Area with peat deposits indicated in black color. This study's field visits and interview areas in Kalimantan are marked with red dots.