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# Community-led peatland restoration in Southeast Asia: 5Rs approach

Dilva Terzano[1,2,3,4], Fabio Attorre[1], Faizal Parish[5], Patrick Moss[2], Fabrizio Bresciani[3], Roshan Cooke[3], Paul Dargusch[2]

**Peatlands in Southeast Asia are of global significance for biodiversity conservation and climate regulation as well as of national and local significance for water management and livelihood support. Despite this, these ecosystems are among the least studied and monitored of the world, and are increasingly threatened by anthropogenic activities. Peatland degradation is responsible for the largest greenhouse gases (GHGs) emission source from the agriculture, forestry, and other land use (AFOLU) sectors in the region. Peatland restoration is a key mitigation and preventative intervention to halt the degradation of these ecosystems. In recent years, a small number of studies have aimed to define peatland restoration processes and approaches, the latest being the 4Rs approach—Rewetting, Reduction of fire, Revegetation, and Revitalization. The latter component being focused on the local communities benefits, in terms of promoting diversified sustainable livelihoods. Based on evidence of successful peatland restoration interventions in Southeast Asia, which we define as being "community-led," we propose a 5Rs approach to peatland restoration instead, with community participation embedded in each component of the approach, beyond Revitalization, as well as in a fifth crosscutting component: Reporting and monitoring (R5). The new community-led 5Rs approach can support the ongoing formulation, refinement and implementation of peatland restoration strategies and activities in Southeast Asia and beyond by achieving ecological restoration goals, while obtaining local communities endorsement and support, needed for the long-term sustainability of the restoration interventions.**

**Key words: community-based restoration, peatland, peatland restoration, socioecological restoration, Southeast Asia**

### Conceptual Implications

- This study summarizes the current guiding principles defining peatland restoration: Rewetting (R1), Reduction of fire (R2), Revegetation (R3), and Revitalization (R4). We argue that in the current 4Rs approach, Revitalization (R4), is the only component engaging local communities, leading to potential failure.
- We present case studies of peatland ecosystem restoration in Southeast Asia, with different types of community participation in restoration components, as well as in monitoring, contributing to their success.
- We therefore propose the 5Rs approach, with community participation embedded in each component, beyond Revitalization, and in a fifth crosscutting component: Reporting and monitoring (R5).
- The new 5Rs approach can help the formulation of peatland restoration interventions in Southeast Asia and beyond.

## Introduction

Peatlands constitute the most important terrestrial ecosystem for carbon storage (FAO 2020). Peatlands are natural areas covered by layers of peat, defined as partially decayed plant material that accumulates in waterlogged, low nutrient, and acidic environments over long time periods (Rydin & Jeglum 2013). Although peatlands cover approximately 3% of the world's surface, they store as much carbon as in the world's vegetation combined, and half as much than in the atmosphere (Yu et al. 2010; Page et al. 2011; FAO 2020). Eleven percent of global peatlands areas are in the tropics, and of that, 56% are in Southeast Asia (~25 million hectares), with an estimated tropical peatland carbon stock of 68.5 Gt; representing 11–14% of global peat carbon (Page et al. 2011; Miettinen et al. 2016; Hoyt et al. 2020), stored to a depth of 25 m (Chin & Parish 2013). Indonesia comprises

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[1]Department of Environmental and Evolutionary Biology, Sapienza University of Rome, Piazzale Aldo Moro 5, 00185 Rome, Italy
[2]School of Earth and Environmental Sciences, The University of Queensland, St Lucia, QLD 4072, Australia
[3]International Fund for Agricultural Development, via Paolo di Dono 44, 00142 Rome, Italy
[4]Address correspondence to D. Terzano, email dilva.terzano@gmail.com
[5]Global Environment Center, Wisma Hing, 78, Jalan SS2/72, 47300 Petaling Jaya, Selangor, Malaysia


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the biggest portion of Southeast Asia's peat carbon stock (57.4 Gt, 83%), covering an estimated 22.5–24.1 million hectares (Hergoualc'h et al. 2018; MOEF 2018), with the largest areas being in Sumatra, Kalimantan, and Papua (Warren et al. 2017), followed by Malaysia (9.1 Gt, 13%) (Page et al. 2011), covering 2.1 million hectares (Daud et al. 2019).

Tropical peatlands are the most diverse peatland environments, supporting many species of global biodiversity importance, with 45% of mammal and 33% of bird species included in the IUCN Red List (Posa et al. 2011). These comprise numerous globally threatened iconic flagship fauna and flora species (Page et al. 2006; Harrison & Rieley 2018), such as the orangutan (*Pongo* spp.), sun bear (*Helarctos malayanus*), and tiger (*Panthera tigris*) (MOEF 2018). In addition to this, peatlands provide fundamental ecosystem services benefitting local and international communities, which include water supply, food, water resource regulation, flood and fire prevention, riverbank stabilization, carbon sequestration and storage, saline intrusion prevention in coastal areas, as well as timber and nontimber forest products (NTFP) (Page et al. 2011; Harrison & Rieley 2018). These ecosystems also contribute significantly to the livelihoods of many poor communities that live in and around these areas, harvesting plant species such as sago (*Metroxylon sagu*) or agarwood (*Aquilaria* sp). Local communities traditionally benefit from peatlands for their subsistence—timber to build their houses, nutrient-rich food and fish to supplement their diet, clean water, and access to medicinal plants—as well as income and well-being (Hergoualc'h et al. 2018).

Peatland ecosystems were relatively undisturbed until the 1980s, but by 2015, only 6% of Southeast Asian peatland areas could still be classed as pristine (Miettinen et al. 2016). In 2015, only 29% (4.6 million hectares) of the peatlands in Sumatra, Kalimantan, and Peninsular Malaysia (representing 63% of peatlands in Southeast Asia) were covered by peat swamp forests compared to 76% in 1990 (or 11.9 million hectares). The remaining areas were occupied by managed land cover types, namely smallholder dominated areas and large industrial plantations—mostly planted with crops more suited to drylands such as oil palm (73%), paper and pulp (*Acacia crassicarpa*, 26%), and rubber (*Hervea braziliensis*) (Miettinen et al. 2016; Dohong et al. 2017). These peatland areas have often been overdrained, leading to significant subsidence and high fire risks.

The drainage associated with land conversion lowers the groundwater table levels in peatland ecosystems, exposing peat soil to aerobic oxidation and fires, leading to subsidence of the peat surface and GHG emissions (Hooijer et al. 2012). The GHG emissions from oxidation of Southeast Asian peatlands has been estimated to be 155–175 MtC/yr. in 2015, equivalent to the combined regional emissions from fossil-fuel and peat fires (Hoyt et al. 2020). Over 90% of peatlands in the region are subsiding (Hoyt et al. 2020), with observed subsidence rates from compaction of up to 75 cm/yr. after drainage events (deforestation or large fires), followed by long-term rates of 1–5 cm/yr. due to aerobic oxidation and loss of peat to $CO_2$ emissions (Hooijer et al. 2012). In the coming decades, as many peatlands are near sea level in the region, these areas will be subject to frequent flooding, inundation, and saltwater intrusion, with resulting loss of productive land (Hooijer et al. 2012; Hoyt et al. 2020).

Moreover, a drastic increase in the frequency, intensity, and extent of peatland fires has occurred over the last 25 years, burning vast peatland areas, releasing GHG emissions and covering Southeast Asia in toxic air pollution or "haze" impacting over 50 million people (Harrison & Rieley 2018). Around 13 million hectares of peatland forests have burned in the last few decades, with fire hotspots including especially the islands of Sumatra and Kalimantan, in Indonesia. The first extensive peatland fires to attract large media attention were during El Niño events of 1997–1998 and 2002, which covered the region in a thick blanket of haze. These fires were later attributed in part to the failure of the governmental 1 million hectares Mega Rice Project and resulting land conversion in Central Kalimantan, Indonesia, terminated by a Presidential decree in 1999 (Dohong et al. 2018). In the severe El Niño year of 2015, fires burned 2.6 million hectares of forest land (of which 0.89 million hectares on peatlands), releasing 0.71–1.75 Gt $CO_2$ into the atmosphere. These emissions accounted for 97% of Indonesia's total $CO_2$ emissions that year, with daily rates of emissions exceeding those of the European Union during the period September–October 2015 (Huijnen et al. 2016; MOEF 2018; FAO 2020).

More than 90% of haze emanating from the southern part of the region results from peatland degradation and fire (ASEAN 2021). Analysis indicated that the 2015 fire and haze event caused an estimated 100,300 premature mortalities, insurgence of respiratory diseases and dramatic economic losses—amounting over $16.1 billion for Indonesia alone (Glauber et al. 2016; Koplitz et al. 2016; Purnomo et al. 2017), as well as socioeconomic challenges for the communities dependent on these peatland areas (Miettinen et al. 2016; Medrilzam et al. 2017). The challenges on the ground are intensifying with more peatlands being converted to plantations or drained (Thorburn & Kull 2015; Page & Hooijer 2016; Taufik et al. 2020), mainly resulting from higher global demand for oil palm—with most land expansion for oil palm plantations located in Southeast Asia, notably in Indonesia and Malaysia (Rhebergen et al. 2020)—and other products.

The sustainable management and restoration of peatlands have been recognized as the primary preventative measures against peatland fires and haze, peatland subsidence, hydrology disruption, and wildfires caused by the drying out of peat resulting from excessive drainage. For this, tropical peatland restoration is considered one of the most cost-effective interventions for climate mitigation—preserving carbon stocks—and biodiversity conservation (Puspitaloka et al. 2021), but also for sustaining local welfare and livelihoods, and building climate change resilience of local communities. In order to inform and support the formulation of peatland restoration activities, we provide an overview of the guiding principles of peatland restoration, and we propose a community-led 5Rs approach, drawing from case studies in Southeast Asia, to be urgently and widely applied along with conservation of pristine peat swamp forests.

## Restoration of Peat Swamp Forests in Degraded Sites: Guiding Principles

Given that Indonesia is home to 36% of all tropical peatlands, more than any other country (Warren et al. 2017), where approximately 50% of peatlands have been degraded (Putra et al. 2018), restoration has been acknowledged in the recently updated National Peatland Strategy (2020–2049) as a strategic priority to halt degradation and improve peatland ecosystem services. For this, Indonesia is one of the most advanced countries in the region and the world to pioneer and pilot sustainable peatland management and restoration approaches.

To expedite its restoration target of 2.6 million hectares of priority peatland fire hotspot islands of Sumatra and Kalimantan by 2024, the Peatland Restoration Agency in Indonesia or Badan Restorasi Gambut (BRG) (established in 2016) has introduced the 3R approach: Rewetting drained peat, Revegetation of fragmented peatland, and Revitalization of local livelihoods (Dohong 2017, 2018). Peatland fires and wildfires being the main cause of peatland degradation, Harrison et al. (2019) also recommended the inclusion of a further step, that is Reducing fire, resulting in a 4R approach, comprised four components as summarized below:

- *Rewetting* (R1) aims to improve the hydrological properties of drained peatlands through building rewetting infrastructures, such as canal blocking and/or backfilling, deep wells and other water management technologies. Rewetting infrastructures designs differentiate based on the land use, for example (1) in cultivation areas, spillway device need to be integrated to regulate the water level (maximum 0.4 m below peat surface), whereas (2) in conservation areas, these devices are not needed.
- *Reducing fire* (R2) aims to address one of the key drivers of peatland degradation, by: (1) developing and enforcing appropriate fire protection, as well as burning regulations; (2) developing and enforcing alternative non-burning methods for land clearance; (3) raising awareness for behavioral change to reduce fire use; (4) resolving land tenure, land access and use related conflict issues.
- *Revegetation* (R3) aims to restore bare peat vegetation cover and improve peat swamp forest ecosystem function through promoting the availability of seedlings, seed transplantation, and enrichment planting. Indigenous and peat adaptive woody species have been shown to be best fit for successful revegetation practices, with provision of seeds through nurseries for collected seed banks, and samplings through seedlings, wildings and stem cuttings.
- *Revitalization of local livelihoods* (R4) aims to provide alternative sustainable and lucrative livelihoods for local communities settled within or adjacent to peatland areas, to create and ensure markets linkages for these livelihoods, as well as raising awareness for fostering behavioral change. This in order to create diversified livelihood alternatives as means for increasing income and welfare but also to build the resilience of these communities. Alternative livelihoods development can be subdivided into three types, (1) water-based livelihoods which comprise of silvofishery, aquaculture and other water-based income generating activities that suit with local conditions; (2) environmental service-based livelihoods, enhancing activities such as ecotourism, carbon management, etc.; and (3) land-based livelihoods which include activities of planting both endemic and adaptive paludiculture species. Paludiculture being a system that combines timber plantation crops with agricultural crops suitable for growing on wet peat (Hafni et al. 2019) that provide NTFPs as local livelihoods without compromising biodiversity, for example jelutung, gemor (*Alseodaphne* spp. and *Nothaphoebe* spp.) and tengkawang (*Shorea stenoptera*) (Parish et al. 2019).

The abovementioned 4Rs approach aims to serve as a model for the formulation of the peatland restoration activities in Indonesia, although the recently published literature on Indonesia (Lestari et al. 2021; Yuwati et al. 2021), Indonesian governmental officials (IFAD 2021), and guidelines developed by Malaysia on oil palm plantation restoration (Parish et al. 2019) still refer to the 3Rs as the guiding approach when presenting Indonesia's restoration efforts, evidence that awareness on the 4Rs approach is not sufficient or that the approach is not widely recognized by policy makers, researchers and practitioners. Nonetheless, the 3Rs and 4Rs approaches are the only attempts found in the literature at defining elements of peatland restoration interventions.

Although developed for the Indonesian context, components of the 4Rs approach have been applied in Southeast Asia, beyond Indonesia: in Brunei Darussalam, Laos, Malaysia, Myanmar, Thailand, and Vietnam (ASEAN 2021). For example, R1 and R3 interventions were combined in the Badas Peat Swamp in Brunei Darussalam where canal blocking and annual tree planting have been undertaken by national and international agencies, research institutes and private sector. In the Pru To Daeng Wildlife Sanctuary, in Thailand, R2 and R3 were mainly followed by local government and NGOs where fire prevention strategies were coupled with identification of plant species suitable for rehabilitation, procedures for seedling preparation, promotion of good planting practices, and provision of tools and equipment. R4 was mainly pursued in peatland areas of the Beung Kiat Ngong, Laos, and Inle Lake, Myanmar, where organic farming training to local communities were held, including on vermiculture (composting), producing natural pesticides, plant and fruit juice containing indigenous micro-organisms, to promote alternative sustainable livelihoods. Whereas the four elements of the 4Rs approach were applied in the North Selangor Peat Swamp Forest, in Malaysia and U Minh Thuong National Park, Vietnam—both landscapes recognized as successful peatland restoration interventions (ASEAN 2021). However, this success is attributable to further refinements and adjustments to the 4Rs approach as detailed in the sections below—mainly the fact that the interventions were led by the community and had a monitoring element.

## Community-Led Peatland Restoration: Success Stories in Southeast Asia

The peatland restoration case studies presented below, comprise different types and levels of community participation in

rewetting (R1), fire reduction (R2), revegetation (R3), in addition to revitalization (R4), as well as in the overall monitoring of these activities—all of which contributing to their success as evidence to support the proposed necessary refinements and upgrade of the approach.

**Community-Led Rewetting (R1).** In the ongoing Sustainable Management of Peatland Ecosystems in Indonesia (SMPEI) project, funded by the Global Environment Facility (GEF) and implemented by the International Fund for Agricultural Development (IFAD) together with the Ministry of Environment and Forestry of Indonesia, community working groups have been established in 14 villages, in Pelalawan, Indragiri Hulu, and Indragiri Hilir districts in Riau province, Indonesia, empowering local community land users as part of the decision making process on the location of the canal blocks, in addition to being active participants in their construction. A total of 312 canal blocks were constructed over an area of 6,060 ha of community land which restored the hydrology of the peatland system, and reduced the risk of wildfires in the area.

Similarly under the *ASEAN Peatland Forests Project* (APFP), which was the first regional project on peatland restoration funded by GEF and implemented by IFAD together with the Association of Southeast Asian Nations (ASEAN). The project supported the implementation of the ASEAN Peatland Management Strategy (APMS, 2006–2020)—seeking to restore damaged peatlands—in Indonesia, Malaysia, Philippines, and Vietnam. The U Minh Thuong National Park in Vietnam—comprised of peatlands, 80% of which had burnt in 2002—was recognized as a Ramsar site in 2015 (WWF 2016), after peatland community-based restoration activities were implemented under the APFP project, including canal blocking construction for peat rewetting.

**Community-Led Fire Prevention (R2).** In Harapan Jaya and Bengkalis, Riau in Indonesia, under APFP, fire management and control training of the local community, establishment of participatory community fire groups and brigades, supported by innovative community regulations for fire prevention, proved to be successful in reducing the risk and danger of fires, contributing to the restoration of surrounding peatland areas. These community-led fire control actions were accompanied by fire prevention training which contributed to raising local awareness on the impact of the use of fire on peatlands as land clearance practice (IFAD 2014). This approach was also applied under the *Technical Assistance and Knowledge Exchange for Sustainable management of Peatland Ecosystems in Malaysia* (TAKE-SMPEM) project, implemented by the Global Environment Centre (GEC), in North Selangor Peat Swamp Forest and South Selangor Peatland Landscapes, Selangor state, Malaysia, where trained local community fire brigades were established to patrol fire prone peatland areas, resulting in a reduction in fire occurrences in those landscapes (GEC 2021).

The traditional *slash-and-burn* practiced by smallholder farmers, that is land clearance using fire (Uda et al. 2020), comes from the misconception that fire converts soil surface biomass into nutrient-rich ash, increasing soil pH, and ultimately soil fertility. It was, however, shown that burning causes the greatest nutrient loss of any forest disturbance (Van Noordwijk et al. 2008). Enhancing the local communities' understanding and awareness of peatland fire related issues and impacts mentioned above is key to achieving restoration objectives (Uda et al. 2020), as well as involving the local community in fire prevention and control, thereby increasing their responsibility over the land they manage.

**Community-Led Revegetation (R3).** In North Selangor Peat Swamp Forest (NSPSF), Malaysia, natural recovery of degraded peatland forest was recorded 5 years after restoration activities were undertaken under APFP. These included community-led encouragement of natural regeneration and replanting of severely degraded areas in support of peatland reforestation. The "Seedling Buy Back System" for forest nurseries was designed to establish partnerships between landowners in the buffer zone and local communities to safeguard and restore peat swamp forests. The system worked well in providing income to local community members, while producing planting stock for the reforestation program on peatlands The "Buying Living Tree Scheme," a micro-finance approach that engaged local communities over 5 years in agroforestry-type reforestation on peatlands by ensuring optimal seedling survival, was piloted in Sebangau, Central Kalimantan, Indonesia under APFP. This scheme was then replicated in the Philippines, by the Bureau of Fire Protection, as one of the innovative finance mechanisms to improve local community livelihoods while facilitating reforestation (IFAD 2014; Charters et al. 2019).

It has been shown that in order to obtain short- and long-term outcomes on peatland areas, the application of an agroforestry-type system should be preferred, such as paludiculture (Hafni et al. 2019; Parish et al. 2019). However, the choice and diversity of the paludiculture species for replanting has been found to be a sensitive issue. Different actors are likely to have different preferences between "ecological" versus "economic" plant species (Page et al. 2009; Giesen & Sari 2018). For restoration to be successful, in addition to their active participation in replanting and nurseries, local communities are to be involved in the planning and decision-making process of these revegetation activities, to avoid conflicts to arise if species selected are perceived as likely to impact negatively on local livelihoods over time (Harrison et al. 2019). Building on the APFP project, in SMPEI in Indonesia and in TAKE-SMPEM in Malaysia, through the working groups, communities are being involved in the decision making process for the selection of revegetation species. This is showing to be an effective practice toward achieving targets under both revegetation and revitalization components (R3 and R4) as species selected for revegetation are those most tolerant to grow on wet peat conditions associated to paludiculture.

**Revitalization (R4).** Under APFP, in the U Minh Thuong National Park in Vietnam, peatland community-based restoration activities were coupled with the introduction of "Green

Contracts" to the local community living in the buffer zone which enabled a diversification of their livelihoods, by integrating fruit and vegetable growing, fish farming and livestock and poultry management as alternative fire-free sustainable income sources. This resulted in a doubling of their annual incomes and eliminated their dependence on the peatland core zone in the National Park (Quoi 2015). In NSPSF, in Malaysia, the "Friends of North Selangor Peat Forest" model included community support for alternative livelihoods such as eco-tourism for wilderness experience and environmental awareness—later recognized by the government as suitable for scaling-up to other peatland areas (IFAD 2014).

In SMPEI peatland areas, Indonesia, demonstration plots are serving as community gardens, aimed at diversifying the agricultural income sources of local communities by intercropping different commodities (e.g. pineapple and lemongrass) which can grow while maintaining ecologically sustainable peat soil moisture. In May 2021, a household survey was undertaken among the SMPEI community working group members, of 12 villages in 3 districts of Riau provinces, namely Pelalawan, Indragiri Hilir and Ingragiri Hulu. 75% of the 152 respondents registered monthly income increase of more than USD 35 as a result of selling the community garden harvest with recorded higher demand for pineapple, red ginger, vegetables, areca nut. Compared to before project start, respondents reported decreased number of monthly income that totaled less than 175 USD (by 15%) and increased number of monthly income of 175–245 USD (by 9%), and of more than 245 USD (by 6%). All project beneficiaries, referred to this factor i.e. impact on income, when expressing their appreciation for the project (IFAD 2021). In SMPEI and TAKE-SMPEM, the assessment of local community needs was developed as part of the project baselines, based on which the target for the revitalization (R4) activities were developed, and discussed among the community working groups, found to thereby incentivize communities to participate in all components of restoration efforts to increase their own benefits.

For a successful revitalization of local livelihoods, the assessment of community needs should be a prerequisite when developing and initiating restoration interventions, in addition to the assessment of the prevailing ecological situation and existing restoration barriers of the peatland site (Page et al. 2009; Graham et al. 2016). Such analysis should form a baseline for setting revitalization and overall restoration targets that are acceptable for all stakeholders in the landscape, including local land users, which should also be involved in the identification of the alternative livelihoods—practice which is proving to be successful under SMPEI and TAKE-SMPEM in incentivizing communities to participate in the restoration efforts.

In the SMPEI and TAKE-SMPEM project areas (in Indonesia and Malaysia), in addition to applying the four elements of the 4Rs approach, the concept of participatory reporting and monitoring is also being applied, where community working groups were also trained to be able to independently monitor key parameters of the restoration process through enhanced community surveillance (GEC 2021; IFAD 2021). These include monitoring: (1) water table level and peat soil moisture (indicators of the hydrological recovery R1); (2) risk, frequency and extent of fires through patrolling and fire danger rating system (FDRS) signboards (R2); (3) seedling survival and effectiveness of revegetation efforts (R3); and (4) increase or stabilization of smallholder farmers monthly income (R4). The projects also developed a reporting mechanism which ensures community working groups maintain a communication and feedback loop with the local government environment agency or authority on the status and monitoring of restoration activities, thereby also allowing the verification of the measured indicators.

The SMPEI survey showed that 76% of the respondents were involved in the construction of the rewetting (R1) infrastructures (canal blocking), of which 28% also in their planning and monitoring. Consequently, all group members (98%) understood the direct link between well positioned and maintained canal blocks and moisture of peat soil, and groundwater table back to a sustainable level (i.e. 0.4 m from surface) as a result from their efforts. Under TAKE-SMPEM, in North Selangor Peat Swamp Forest and South Selangor Peatland Landscapes, Selangor state, Malaysia, local community teams were established to monitor fire prone peatland areas and update the FDRS signboards with readings warnings received from Malaysian Meteorological Department (R2) as well as have been taking water level readings (R1). This active participation of local community in the monitoring of fire risk, through patrolling and FDRS signboards interpretation, resulted in having increased their understanding of implications of lowered fire risk on their livelihood and health and related perceived impacts as shown by a field survey undertaken in June 2021. This, has also been shown to have a direct link with willingness of local communities to continue these efforts beyond project life, local ownership of the full set of restoration activities and understanding of the peatland ecosystem (GEC 2021). Participatory monitoring therefore serves as a tool to provide first hand evidence to the local communities on the actual impacts resulting from the rewetting (R1), fire reduction (R2) activities, and overall restoration interventions. Ultimately, serving as an incentive for community working group members to continue participating in the maintenance and monitoring of the canal blockings, or fire patrolling and prevention, after project completion, as concluded the survey.

These projects show that empowering local communities as active players in the restoration activities—for example, from planning and construction of canal blocking (R1), to prevention of wildfire and fire control (R2), to selection of species for revegetation and maintenance of nurseries (R3), in addition to livelihoods diversification (R4)—as well as in reporting and monitoring is an appropriate approach. This community-led approach have been replicated in more than 50 villages across Indonesia, in Aceh, North Sumatra, West Sumatra, West Kalimantan, Central Kalimantan, and East Kalimantan and will be replicated in Riau, Jambi, and South Sumatra provinces of Indonesia, through the GEF-IFAD IMPLI project, and to Sabah, Sarawak, Selangor, and Pahang states of Malaysia, through the GEF-IFAD SMPEM project, both started in 2021, and may be adopted elsewhere (IFAD 2021).

## Proposed Community-Led Restoration Approach: 5Rs Approach

A revised definition of peatland restoration has been recently proposed by Puspitaloka et al. (2020), recognizing the need to account for the social context, and the importance of multi-stakeholder collaboration. The recently published review of the APMS acknowledges that local communities are key stakeholders in peatland management in Southeast Asia, and that the next phase of the regional APMS should strongly support community-based peatland stewardship and sustainable use (ASEAN 2021). A recent study in Indonesia found that local community involvement is increasingly being perceived as crucial to restoring peatlands based on interviews to a range of stakeholders, from policymakers, to academics and NGOs (Ward et al. 2020). However, these growing acknowledgements, perceptions and definitions, need to be substantiated by a tailored restoration approach for urgent and wide application.

Integrated landscape management approaches—the landscape being the Peatland Hydrological Unit (PHU) in our case—assume involvement and collaboration between key stakeholders of the landscape, from government agencies, large-scale private sector plantations, NGOs as well as local communities (Graham et al. 2016). Participatory or community-based landscape approaches go a step further, making local land users an integral part of the planning and management processes as stakeholders. We refer to land users given the unclear land tenure and access rights in most of these areas in Indonesia, with 70% of smallholder palm oil plantations not having land titles (Purwanto 2020). Unclear land tenure and access rights are widely acknowledged as important drivers threatening the achievement of peatland rewetting and fire-fighting goals, leading to conflicts and lack of accountability (Medrilzam et al. 2014). For example, in SMPEI project areas, 80% of community working group surveyed were land users, however only 48% were land owners (70% of which owning less than 2 ha, 18% owning 2–4 ha, 9% owning 4–6 ha, and the rest owning more than 6 ha).

Although it is widely recognized that social inclusion must be at the center of the ecosystem restoration agenda, restoration approaches have favored the ecological dimension at the landscape or ecosystem scale, over the social dimension at the community scale. The latter often focussed on productivity-based incentives alone as proxy for successful social inclusion (Sigman & Elias 2021). Social-ecological restoration approaches (1) prioritize livelihood needs of local communities; (ii) recenter people-ecology relations on cultural values; and (3) require financial resources to support local community to embark in restoration activities (Fernández-Manjarrés et al. 2018). For over two decades, decentralized ecosystem governance models, such as community-based ecosystem management, have been promoted in the literature as a means of achieving local livelihood and well-being benefits while also promoting ecosystem conservation, restoration, or sustainable natural resources management (Agrawal et al. 2008; Calfucura 2018; Friedman et al. 2020; Cole et al. 2021). This concept is to be applied in the context of peatland ecosystem restoration, supporting the idea that long-term restoration success and sustainability is dependent on the level of local community support and ownership of these activities (Manalu 2020).

Peatland ecosystem resilience is inextricably linked to the well-being of the communities living within them (Herawati et al. 2019). In Indonesia, 75% of peatlands are in community (nonconcession) land (MOEF 2018), where approximately 16.3 million people residing within and dependent on forest and peatland areas (Puspitaloka et al. 2020). Given that Indonesia's peatlands represent 91% of Southeast Asian peatlands, these figures show the importance of the local community in managing this ecosystem in the region. In the case of oil palm representing 73% of the crop cultivated on peatlands in Indonesia (Miettinen et al. 2016), smallholder farmers (<2 ha) manage 40% of plantations in both Indonesia (where 2.6 million smallholders manage 5.8 million hectares of palm oil plantations) and Malaysia. The remaining ∼60% is attributed to large private-sector companies. Given the lack of income generation and agriculture production alternatives, smallholder farmers are increasingly engaging in oil palm cultivation due to its perceived lucrative nature.

Nonetheless, local land users are still only minor players in peatlands and forest protection and restoration due to their lack of capacity, knowledge, and the limited support from relevant stakeholders and authorities. In countries like Indonesia, with an ambitious peatland restoration target, and beyond, local communities should be at the center of restoration activities to ensure their endorsement and the long-term sustainability of these activities. To be successful in the long-term, restoration of these ecosystems should not only address the needs of these marginalized populations (R4), their capacity and knowledge should be strengthened and their active participation should be ensured in all components of the restoration interventions. More attention should be paid, as well as roles and responsibilities should be given to this category of land users in the context of restoration interventions undertaken in the land they are using. Recognizing the roles and rights of land users and empowering them through participatory approaches will provide these stakeholders the long-term incentives to support restoration activities.

In the 4Rs approach, Revitalization (R4) is the only component with clear active participation of local communities—being focussed on their benefits, in terms of promoting diversification and environmental sustainability of their livelihoods and income sources. Whereas R1, R2, and R3 components appear to be decoupled from the local communities and the sole responsibility of the relevant authorities, for example local governmental environment agency, private sector concession land owners, NGOs, etc. However, in line with the literature on community-based ecosystem management, local communities should be at the center of the approach, empowering them as key active stakeholders and managers, beyond the Revitalization (R4) component. For the long-term sustainability of restoration interventions, community participation cannot be at the periphery of the approach or as a stand-alone component (R4 in the 4Rs approach).

It was shown that failure to involve the local community, or to provide clear understanding of the benefits of these activities to the community can compromise the restoration efforts

altogether. Peatland restoration interventions have often failed because of the multitude of stakeholders in the landscape with conflicting needs and goals (Fleming et al. 2021). In Indonesia, governmental-led peatland rewetting activities (R1), with no involvement or information to the local community, resulted in local misconceptions and resistance of the benefits of the restoration activities, ultimately leading to communities destroying the dams (Harrison et al. 2019), or draining back the land for agriculture (Manalu 2020). Local negative perceptions of canal blocking on fish population, material (e.g. timber) transport and local community mobility have been reported in Central Kalimantan (Harrison et al. 2019) when communities were not involved in the planning and implementation of rewetting activities. Another study in South Sumatra, Indonesia, found that rewetting activities (R1) undertaken by BRG have not had a significant impact restoring peatlands (Lestari et al. 2021). These activities were often poorly understood by local communities, attributable to the fact that local community were not widely engaged in the activities. Only those that were directly involved in the restoration activities fully understood and endorsed the rewetting activities. General feeling recorded from the local community was that their lives would be better off without the peat, because they could grow higher yield crops, often seen as a barrier to achieve optimal production or land use (Lestari et al. 2021). Not only are local communities' awareness of the benefits of canal blocking necessary for the acceptance and understanding of restoration activities, their participation in canal blocking construction and maintenance as well as water table level monitoring are key for the sustainability of peatland restoration interventions.

In addition, the 4Rs approach also does not include or clearly define its monitoring, reporting or evaluation elements. Harrison et al. (2019) only mention that monitoring and evaluation should be part of all 4Rs, leaving this aspect assumed to be managed by local authorities, as conventional processes. Monitoring is an important component for evaluating restoration success and assessing impact at local scale and beyond. There is growing recognition that participatory approaches should also include participatory monitoring, considered to be cost-effective in data collection while empowering local communities (Turreira-García et al. 2018). It was shown that community-based monitoring systems in peatland areas can serve as more efficient alternatives to conventional systems. By involving the local communities in the monitoring process, it was found that costs are reduced, monitoring area coverage is increased, and restoration impacts on ground water level and peat soil moisture are effectively measured. Moreover, it was also shown that the participatory nature of this type of monitoring process and system empowers the local community to restore and conserve these ecosystems. Data collection software (e.g. Kobotoolbox and others) operated by locals via offline mobile devices, for submission of data to an online monitoring database, allows community-based reporting and monitoring to provide data in a periodic and timely manner (Okarda et al. 2019).

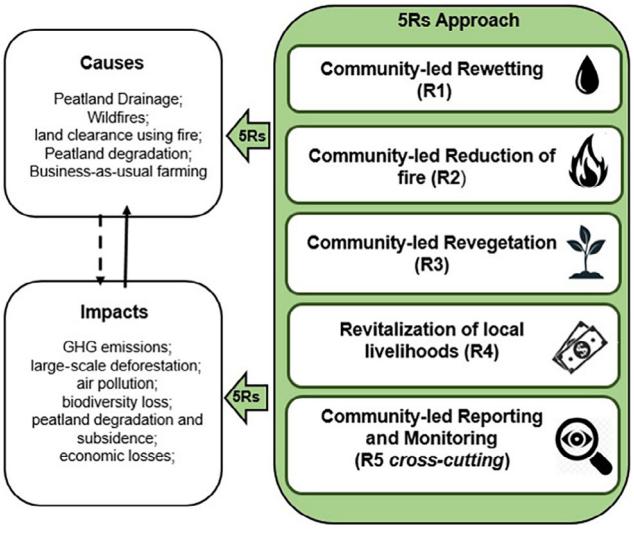


Figure 1. Conceptual diagram of the 5Rs approach. Adapted from Dohong et al. (2017), Harrison et al. (2019).

For the community-led monitoring and reporting to work, baselines and targets are to be made accessible to and understandable by local land users. Similarly to SMPEI in Indonesia and TAKE-SMPEM in Malaysia presented, capacity building training and awareness raising workshops are to be provided to the community working groups through Community Facilitators on reporting, monitoring as well as all other components of the restoration approach. By clearly defining the variables or indicators to be monitored, the modality of monitoring, as well as the reporting systems.

The addition of the Reporting and monitoring (R5) component will therefore ensure the completeness of the approach, and the clarity that potential success will be ensured by enabling full involvement of the community in the continuous checking and assessment of the restoration activities, allowing first-hand exposure to concrete results, ultimately increasing ownership, and further potential replication, as shown by the surveys undertaken in Indonesia and Malaysia.

We here presented case studies and literature from Southeast Asia showing that community-led approaches are more effective alternatives to conventional restoration approaches (including community-led monitoring), and should be prioritized in the context of community land for the long-term sustainability of the restoration interventions. Based on these studies, we propose a community-led peatland restoration approach to be applied at the PHU level, as shown in Figure 1, which acknowledges the active driving role that the local community has to play in each component of the approach, beyond Revitalization (R4), and in an additional component Reporting and monitoring (R5).

## Conclusion

As re-iterated at the UNFCCC COP26, tropical peatland restoration is considered as one of the most cost-effective climate change mitigation interventions. Southeast Asia comprising the majority of the world's tropical peatlands, all eyes are on the region to scale-up efforts in the context of global climate mitigation as well as the Bonn Challenge and the United Nations Decade on Ecosystem Restoration (2021–2030), aimed at restoring 350 million hectares of degraded ecosystem globally

by 2030 (Sigman & Elias 2021). Despite substantial progress being made on several fronts, the problem of peatland degradation and resulting transboundary haze pollution in Southeast Asia has yet to be brought fully under systematic control, and requires restoration approaches to be formulated appropriately for immediate and wide-spread application.

The proposed 5Rs approach can inform the effective formulation, and implementation of peatland restoration interventions in Southeast Asia and other peatland countries. Implementation of the 5Rs approach requires appropriate local community capacity building to be undertaken by local government or NGOs, and establishment of community working groups at the village level. Women and youth participation in community working groups and restoration activities should be fostered, given their active role in household income generation in peatland areas (Herawati et al. 2019). Indigenous people living in and adjacent to peatlands have been shown to be effective stewards for these ecosystems and custodians of traditional knowledge, and their engagement should comply with Free, Prior and Informed Consent principle. Civil society can be a key partner to facilitate engagement of local stakeholders for fostering participation and behavioral change, as well as engaging the public to enhance knowledge and awareness on the importance of peatland ecosystems services. Further, incentives could be applied for villages that have implemented zero burning and restoration practices for further roll-out of the approach (ASEAN 2021). Keeping the momentum generated at the COP26 and capitalizing on ongoing commitments demonstrated by Southeast Asian countries will be essential for knowledge sharing and south–south cooperation between Southeast Asia and other peatland countries in the world to facilitate further commitments and immediate action on the ground.

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