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Community-based fire prevention and peatland restoration in Indonesia: A participatory action research approach

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ABSTRACT

The vast majority of peatlands in Southeast Asia are located in Indonesia. They are currently classified as degraded and at risk of fire. Fire prevention and the restoration of degraded peatlands have therefore been part of the national government's agenda for the last two presidential terms. With the immense pressure of anthropogenic challenges, interventions to restore degraded peatlands and prevent fire combine biophysical and socioeconomic considerations. This paper explores the implementation of community-focused interventions and participatory processes in fire prevention, peatland restoration and sustainable livelihood improvement in Bengkalis Regency, Riau Province. We used Participatory Action Research (PAR) and an Institutional Analysis and Development (IAD) framework to foster an on-the-ground and inclusive process for behavioral changes that result in not using fire in agricultural land preparation and to advance awareness of and participation in restoring degraded peatlands. Our findings reveal that PAR, with an IAD framing, can catalyze change. Four critical aspects are required for this: (a) demand for the intervention; (b) adequate political support; (c) community participation, leadership, social capital and local institutions; and (d) business models for sustainable livelihood transitions. This paper provides lessons on scientifically driven and evidence-based participatory processes for restoration.

1. Introduction

The economic disruption and health impact caused by haze from forest and land fires have been enormous. In 2015, Indonesia's forest and land fires exposed 43 million people to haze (Koplitz et al., 2016) – half a million people suffered from acute respiratory infection, and economic losses amounted to USD 16.1 billion (Glauber and Gunawan, 2016). The fires destroyed 2.6 million hectares of land, of which 33% is peatlands (Indonesia's National Agency for Aviation and Space, 2015). The fires were human-caused, and driven by political factors (Purnomo et al., 2019) and economic rents (Purnomo et al., 2017). These fires led to significant greenhouse gasses

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emissions (Huijnen et al., 2016; Field et al., 2016), of which majority (71%) was caused by fires on peatlands (Kiely et al., 2021). The high rainfall combined with efforts in and enforcement of fire prevention, such as early detection, monitoring and law enforcement, despite some gaps prevailing, have contributed to fire reduction (Aminah et al., 2020). This is demonstrated by a significant decline in fire occurrence in subsequent years, as indicated by the Ministry of Environment and Forestry's (MoEF) monitoring system. However, the fires occurred and peaked in 2019, which affected 1.65 million hectares of land (MoEF, 2021). This caused a USD 5.2 billion loss (World Bank, 2019) and emitted at least 708 megatons of CO_2e (Copernicus Atmosphere Monitoring Service, 2019).

The greenhouse gasses emitted during fire occurrences may not be balanced by re-growth following fires (van der Werf et al., 2010). The loss caused by fires impacted a wide range of sectors and the transboundary toxic haze affected neighboring countries. Globally, peatland fires also contribute to global warming, reduced temperatures and light intensity, and potentially influence the El Niño Southern Oscillation (ENSO) (Harrison et al., 2010). To avoid further ecological collapse, post-fire degraded peatland restoration is fundamental. This would help to reduce the risk of fire occurrences and restore invaluable ecosystem services. Indonesia's approach to peatland restoration, led and coordinated by the Peatland Restoration Agency (BRG), focuses on rewetting degraded peatland, revegetation or replanting peatland, and revitalizing livelihoods (BRG, 2016). There are also various initiatives undertaken at different levels by stakeholders. The Government of Indonesia established Government Regulation (*Peraturan Pemerintah*/PP) No. 57/2016 on peatland management and conservation, MoEF decrees to operationalize the PP, and a Grand Design for Fire Prevention 2017–2019, led by the Ministry of National and Development Planning. Recently, the government has shifted 60% of its fire prevention efforts to address the indirect causes of fire (Ministry of National Development and Planning and Coordinating Ministry for Economic Affairs, 2017).

It is doubtful whether government action alone can really reduce fire, given the enormous 'fire profit' of actors and their complex relationship with elites (Purnomo et al., 2017). All parties, including central and local governments, the private sector, communities and civil society organizations (CSOs) must act together in a coordinated manner to restore degraded peatland and prevent fires. Many approaches, including BRG, involve interventions that focus on the community level that recognize anthropogenic factors (BRG, 2016; Puspitaloka et al., 2020). Community-focused interventions and participatory processes need to be understood to further refine the approach and to address the indirect causes of degraded peatland and to encourage fire prevention. Research on how to understand and bring communities together with other stakeholders to prevent fire is needed. Donors and stakeholders also demand research that catalyzes change at the local level, with participation and ownership of the community and immediate outcomes. To engage with these rationales, we employed a Participatory Action Research (PAR) method.

PAR involves a process where the community plays a role as co-researcher to identify problems, collect and analyze information, and identify potential solutions – which further encourages social and political transformation (Selener, 1997). It facilitates collaborative adaptive management (Colfer, 2005) through the loop of 'reflection-planning-action-monitoring' (Henocque and Denis, 2001). It is closely related to general system theory, complexity theory, communicative action (Habermas, 1987), the socio-ecological system (SES) (Ostrom, 2007), and Institutional Analysis and Development (IAD) (Ostrom, 2010). The Center for International Forestry Research (CIFOR), in partnership with the Center for Disaster Studies of the University of Riau (PSB UNRI), implemented a PAR framework for community-based fire prevention and peatland restoration, aiming for on-the-ground behavioral changes that involve inclusive processes that encourage the community to not use fire in land preparation and foster more awareness of and participation in restoring degraded peatlands. We employed PAR to respond to the following questions.

1. How can we effectively encourage local stakeholders to work together to prevent fires and restore peatlands?
2. What kind of business models can help local communities include more sustainable livelihood practices related to peatlands?
3. How can we monitor, and what are the research outcomes and impacts?
4. How can PAR impacts be scaled out?

We hope this paper provides lessons for other stakeholders with similar foci to carry out scientifically driven and evidence-based participatory processes at the local level to produce clear outcomes and impacts. We expect to share lessons learned through community engagement to support the agenda of peatland restoration and fire prevention.

2. Methods

The overall framework of the study uses Institutional Analysis and Development (IAD) (Ostrom et al., 1994, 2010). IAD describes how actors exist in a certain action arena and are driven by their context, which includes the physical world, their community, and rules-in-use or institutions. At the heart of the framework is an 'action arena', consisting of 'actors' who are the key individuals and groups, and an 'action situation', which is the social space where individuals or groups of individuals interact, and outcomes. The actors interact to pursue aims, change behavior, and achieve their interests and goals in the 'action situation'. This leads to outcomes that can be evaluated with certain criteria.

We aligned the IAD framework with PAR to generate and catalyze change. PAR is an inclusive process through which members of a community identify a problem, collect and analyze information, act to find solutions and promote social and political transformations (Selener, 1997). This method is uniquely different from other conventional research methods due to the principles it embraces. PAR enables and values the participation of people. It provides freedom, life-enhancements, and enables the expression of human potential (Stringer, 1999 in MacDonald, 2012). In PAR, people or a community act as co-researchers who actively contribute to and participate in the research process (Chandler and Torbert, 2003; Kelly, 2005 in MacDonald, 2012). Through PAR, local communities can act collectively and participate in decision-making processes involving their forests and lands. It is executed using loops of phases

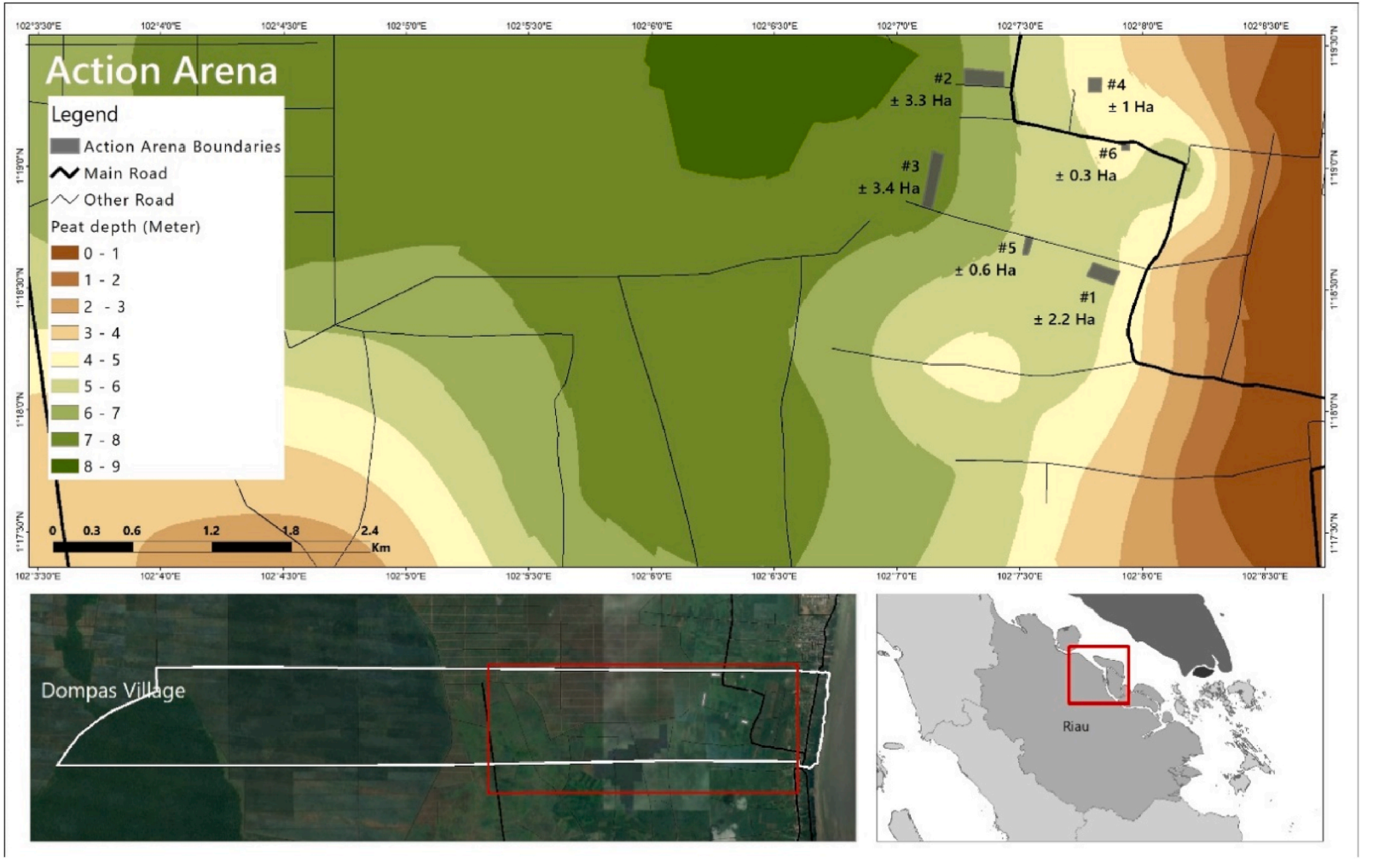

Fig. 1. Map of the Participatory Action Research area in Dompas Village where CIFOR-PSB UNRI facilitated six action arenas (11.1 ha) and 311 household home gardens. The peat depth map was produced by the researchers and communities.

(Henocque and Denis, 2001) that foster the adaptive and collaborative capacity of local communities (Colfer, 2005).

We carried out PAR fire prevention and peatland restoration for three years from 2018 to 2020 in Bengkalis Regency, Riau Province, Indonesia. Riau holds nearly 10% of Indonesia's peatlands (CIFOR, 2021) and experiences the most frequent fires in Indonesia (Sizer et al., 2014). About 183,809 ha of forest and land were burned in 2015, and 90,550 ha in 2019 (MoEF, 2020) – these constitute 7% and 5% of the total burned area nationally, respectively. This area experienced massive forest conversion to palm oil plantations and has the greatest area of palm oil plantations in Indonesia, totaling 2,895,083 ha or 19% of total oil palm plantations in Indonesia (Directorate General of Estate, Ministry of Agriculture (MoA), 2021). PAR primarily took place in Dompas Village, but activities and dissemination of information also occurred at the district, provincial and national levels. Dompas Village includes 1,129 ha of non-forest estate *(Area Penggunaan Lain/APL)*; 59 ha of protection forest; 3,856 ha of permanent production forest; and 1,682 ha of convertible forest (Fig. 1). The village was selected due to the presence of degraded peatlands, its fire history and forest area. The village has an active farmers group and a fire care community. Village members were willing to collaborate, share their knowledge and experiences; and had also shown interest in participating in the PAR process.

We conducted about 59 FGDs and field activities, at minimum, throughout the course of PAR. The process began with 'reflection' (August to October 2018) on the problem at hand, the desired goal, and evaluation of existing and best practices. We collected socioeconomic, i.e. through household survey at the beginning and closing of the project, and biophysical field data, i.e. soil and biophysical survey, consulted with stakeholders, organized FGD, conducted field visits and reviewed relevant cutting-edge science. In PAR, FGDs are an essential tool to establish communication and public discourse and to define shared values and common ground for better partnerships and participation (Arnstein, 1969). Researchers worked as facilitators to help stakeholders recognize their problems and suggest options for solutions. We then supported the community in co-developing an action plan for biophysical, socioeconomic, and institutional engineering in the Planning Phase. The action plan includes the development of a sustainable business model on peatlands using a business model canvas (Osterwalder and Pigneur, 2010), a landscape engineering plan, a cost-benefit sharing mechanism, and an institutional transformation plan. We treated this action plan as a set of hypotheses to be tested. We then facilitated the implementation of the action plan during the Action Phase through seven action arenas that spanned 11.1 ha and 311 household home gardens. The action arenas served as the content to test the hypotheses, and the community, as co-researcher, executed the action plan in these arenas, reflecting on the lessons learned and best practices identified in the earlier phase. The data generated in the action plan were monitored in the Monitoring Phase. We developed CO-PROMISE (a Community-based Peatland Restoration Monitoring System) – an information technology and community-based monitoring system. It aims to provide a database with spatial information on the results of the monitoring of restoration activities. The system utilizes the Open Data Kit (ODK) platform which consists of the ODK Collect application on Android and KoBo-Toolbox, a cloud storage system integrated with Microsoft Power BI for online data visualization (Okarda et al., 2022). With the community, we facilitated the periodic monitoring and collection of tree and crop survival and growth, and ground water level measurements. Plants survival and growth were measured in the action arena #1, #4, and #7. Crops such as pineapple in action arena #2 and #3 were measured for the number of planted crop and harvested crop. Action arena #5 and #6 were not quantitatively measured at the time of the project. The results were published on the CO-PROMISE dashboard and used to conclude if hypothesized actions produced the desired outcomes.

3. Results

3.1. IAD framework implementation

We used the IAD framework to identify the components of biophysical, socioeconomic, and institutional arrangements (rules-in-use), along with the exogenous variables that influence these components (Fig. 2). The biophysical landscape in Dompas consists of primary and secondary forests, mixed gardens, monoculture rubber and oil palm plantations, shrubs and post-fire, abandoned land. A portion of its landscape is dominated by two commercial, large-scale oil palm and industrial timber plantations. The village primarily comprises deep peatlands 400–800 cm deep (83%) and shallow peatlands 50–100 cm deep (Wetlands International, 2003). Nearly 70% of the deep peatlands are located on permanent production forest, while the shallow peat is on residential and smallholder plantation areas. The community considers the peatlands to hold important roles in supporting the local economy and maintaining environmental services, especially the hydrological functions of peatland. They identified the peatlands as a food source, flora-fauna habitat, freshwater source, carbon sink, and farming land. However, most of the peatlands are degraded, driven by land use conversion, drainage canals on peatland, illegal logging, heavy machinery and agricultural practices that involving drainage of the peatland. This has caused the peatlands to be dry and prone to fire. Based on our household survey, more than half (57%) of the sampled households acknowledged the history of forest and land fires on their land. Nearly half (46%) stated that their land had a high and very high risk of fire. Fires are driven by climatic conditions and deliberate burning (i.e., land preparation using fire). They acknowledged that the degraded peatland conditions of Dompas lead to a high risk of fire. The village leader argued that routine fire patrol monitoring is the most effective method for preventing fire. However, there are ways to permanently reduce the risk of fire through restoring the dry and degraded peatland. About 70% of respondents considered restoration to be very important. The approach to replant the peatlands was the most identified approach stated by respondents. Since the beginning of the project, the communities and government demanded and supported fire prevention and peatland restoration efforts.

In the socioeconomics component, we identified the immense pressure on peatlands due to livelihood and development needs. There is also a lack of knowledge and capacity on sustainable practices and business models. The village is inhabited by 4,000 people, mostly belonging to the Malay ethnic group. They had mainly graduated from elementary and junior high school. They were mainly farmers of rubber, palm oil, coffee, cinnamon and horticulture; animal breeders; or oil palm plantation labors. The agricultural sector is

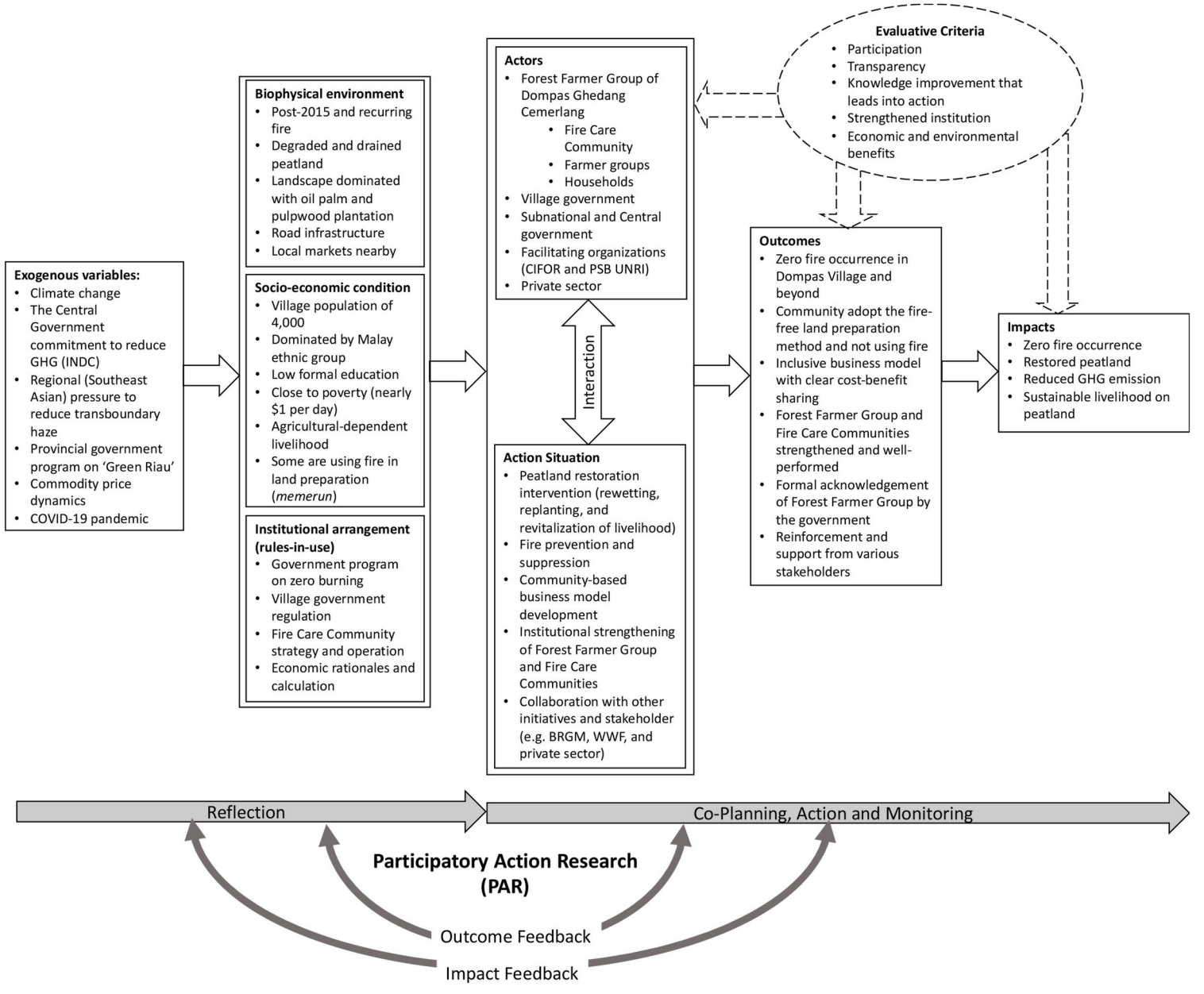

Fig. 2. PAR results as framed with IAD.

the main source of income and most agricultural practices are carried out on peatlands. Some communities are still practicing *memerun*, a traditional practice that involves fire in land clearing. We then facilitated a transition process through capacity and knowledge building to help the community understand, chose, and adopt fire-free land preparation options and peatland restoration practices. We also facilitated the development of more sustainable business models with commodities and practices that are more suitable for peatlands.

In terms of institutional arrangements, the village government regulations, economic rationality, fire care community and farmer group operations and strategy are the rules-in-use for fire prevention and peatland restoration. After severe forest and land fires in Indonesia in 2015, law enforcement on the use of fire became stricter, including at the village level. The village government formed a fire care community, a voluntary initiative that consists of 10–15 volunteers who carry out early detection and suppression of fire.

Table 1
Profiles of the actors, action arenas, and their performance.

	Action arena #1	Action arena #2	Action arena #3	Action arena #4	Action arena #5	Action arena #6	Action arena #7
Actor/land manager	*Fire care community (15 persons)*	*Women farmer group (21 persons)*	*Men farmer group (15 persons)*	*Farmer household (4 persons)*	*Farmer household (4 persons)*	*Farmer household (4 persons)*	*Household (311 households)*
Socioeconomic condition of the actors (pre-restoration)	A group of unpaid volunteers for fire patrol and suppression without sufficient knowledge on peatland and assurance of operational costs for the fire patrol and suppression	A women farmer group, consisting of women working as farmer, laborer, and housewife with low income	A male farmer group consisting of farmer and laborer with low income	A farmer household with low income and capital	A farmer household with low income and capital	A farmer household with low income and capital	Villagers of Dompas, with majority live in poverty and generate low income
Tenure	Public land (village-owned)	Co-managed land (owned by villagers and managed by farmer group)	Co- managed land (owned by villagers and managed by farmer group)	Private land (owned and managed by farmer household)	Private land (owned and managed by farmer household)	Private land (owned and managed by farmer household)	Private land (owned and managed by villagers/ households)
Biophysical condition (pre-restoration)	±2.2 ha with flat topography covered with shrub and trees and some presence of planted *Shorea* sp	±3.3 ha of post-fire area with flat topography covered by dense shrub and fern	±3.7 ha of post-fire area with flat topography covered by dense shrub and fern	±1 ha of smallholder rubber plantation with relatively clean from shrub	±0.6 ha of smallholder rubber plantation with dense shrub and fern under canopy	±0.3 ha of smallholder rubber plantation with relatively clean from shrub	Home garden of the villagers/ households of Dompas
Peat depth	4.89–6.75 m	5.95–6.47 m	7.0–7.46 m	4.4–5.5 m	5.4–5.8 m	4.1–4.9 m	Varies
Business model	Trees and multipurpose tree species; and fishing-ecotourism	Pineapple agroforestry	Pineapple agroforestry	Liberica coffee agroforestry	Liberica coffee agroforestry	Liberica coffee agroforestry	Hybrid coconut (home garden agroforestry)
Land preparation method	Fire-free manual land clearing with restricted and supervised herbicide application	Fire-free manual land clearing with restricted and supervised herbicide application	Fire-free manual land clearing with restricted and supervised herbicide application	Fire-free manual land clearing with restricted and supervised herbicide application	Fire-free manual land clearing with restricted and supervised herbicide application	Fire-free manual land clearing with restricted and supervised herbicide application	Fire-free manual land preparation
Planned hydrological engineering and monitoring	Pond, canal blocking reconstruction, and build water table monitoring dip well	Canal blocking, pond, and build water table monitoring dip well	Canal blocking and build water table monitoring dip well	Maintain the pond and build water table monitoring dip well	Canal blocking and build water table monitoring dip well	Canal blocking reconstruction and build water table monitoring dip well	Not applicable
Performance score (1= poor; 5=excellent)	4	5	2	5	1	3	4
Key factors influencing performance	• Group cohesiveness • Active group leader	• Collective action and social capital of the women group • Motivation to prove that women can be as good as men	Lacking leadership and collective action	High motivation and family leadership	The leader has health issue	Fair family action	High motivation from individual household

<table>
<tr>
<td rowspan="2">Key partners
• Plantation company
• Watershed Management Agency
• Government Tourism Office
• Village-owned Enterprise
• Bina Cinta Alam Siak (community gorup)
• Fish seeds supplier in Siak Kecil
• Local fish agent/trader/merchant
• CIFOR and PSB UNRI</td>
<td>Key activities
• Land preparation, planting, and harvesting
• Construction of fish pond, hut, gate, fence, and track
• Survey for seedling supplier
• Feeding the fish and maintenance
• Transporting fruit and fish to the market/ agent/ trader/ merchant</td>
<td rowspan="2">Value proposition
Nature-based tourism of peatland with native fish and multipurpose tree species</td>
<td>Customer relation
• Promotion at fishing community
• Advertisement on social media on fishing competition
• Mouth-to-mouth marketing
• Build good relationship with fish agent /trader/merchant</td>
<td rowspan="2">Customer segment
• Local community
• Fisher and fish agent/ trader/ merchant in Pakning, Siak, and Pekanbaru
• End consumer</td>
</tr>
<tr>
<td>Key resources
• Financial and human resource capital
• Land
• Seeds and fertilizer
• Material and tools for pond, fencing, hut, gate, track, and parking lot construction
• Pond, hut, and supporting facilities</td>
<td>Channels
• Road
• Online platform
• Local market and agents</td>
</tr>
<tr>
<td colspan="3">Cost structure
• Multipurpose tree seedling and fertilizer
• Fish seeds
• Equipment for pond, hut, fence, gate, track and parking lot construction, and land preparation
• Materials for pond fencing, hut, gate, track, and parking lot construction
• Equipment for the restaurant
• Worker wage and salary for operation and fire patrol</td>
<td colspan="2">Revenue stream
• Fishing membership and admission ticket
• Fishing equipment sale and rent
• Fruit and fish sale
• Restaurant
• Parking fees
• Miscellaneous goods sale</td>
</tr>
</table>

Fig. 3. Business model canvas for action arena #1.

Although limited, the village government allocated funding to support their operations. Various actors, such as NGOs, also provide short-term programs and aid for a fire-fighter program (World Wildlife Fund/WWF and Friends of the Earth Indonesia/WALHI); fire suppression training and knowledge sharing (Manggala Agni); the construction of peat canal blocks (WWF, United Nations Development Programme, CIFOR, PSB UNRI); seedling programs (Bina Cinta Alam Siak and WWF); and welfare improvement programs (village government). While these programs are essential to build capacity and provide facilities, it is the economic rationality that partly drives the decision-making of the community to manage their land. The local community indicated their preferences for palm oil (43%) over other commodities such as rubber (23%), multipurpose tree species and others. Spatial analysis conducted between 2012 and 2017 indicates that these preferences align with an increase in oil palm plantations by 324 ha, and a decrease of rubber plantations by 126 ha. Some of the action arena under PAR intervention were carried out in smallholder rubber plantation, which were subject to be converted to oil palm plantations. Due to the high cost of developing the plantation and after discussion on the peatland restoration and fire prevention program, the land owner chose to join the program and enrich the planting with liberica coffee and hardwood trees.

Exogenous variables influenced the biophysical, socioeconomic, and institutional arrangement components. Globally, we identified that climate change has influenced the occurrence of extreme weather. There is now an abnormal and longer dry season, which, in combination with fire use for land preparation on degraded peatlands, has contributed to fire occurrence and greenhouse gas (GHG) emissions. At the regional level, the Association of Southeast Asian Nations (ASEAN) has promoted zeroing transboundary haze. ASEAN provides pressure and regulatory support, which has resulted in Indonesia's ratification of the ASEAN Agreement on Transboundary Haze Pollution into Law No. 26/2014. Indonesia was the last ASEAN member state to ratify the agreement after it was rejected by the parliament in previous years (Hurley and Lee, 2020).

At the national and subnational levels, we identified the presence of central and provincial government initiatives to reduce GHG emissions. This was demonstrated by the establishment of Indonesia's Nationally Determined Contribution (INDC), Indonesia's Peatland and Mangrove Restoration Agency (*Badan Restorasi Gambut dan Mangrove*/BRGM), and the Green Riau initiative. The first INDC specifically includes a peatland restoration agenda (Government of Indonesia, 2016). The BRGM is the key actor in leading the coordination of, and facilitating peatland and mangrove restoration at the national and subnational levels. Part of the approach involves revitalizing livelihoods to support more sustainable alternative livelihoods on peatlands. The Green Riau initiative covers initiatives related to forestry, peatlands, and blue carbon (Riau Agency for Development and Planning, 2020). At the local or community level, price dynamics and markets have influenced community commodity preferences, which are driven by high sales prices, easy maintenance, easy market and community access, and land suitability.

3.2. Restoration intervention and community-based business models

The Fire Care Community, farmer groups, households, village governments, and researchers were the 'actors' who actively engaged in fire prevention, peatland restoration, livelihood improvement and local institution strengthening. The interaction occurred in the action arenas guided by the action plan, and an agreed common vision on collaborative action was developed during the Planning Phase. The action arenas represented the diversity and complexity of land ownership, biophysical conditions, and land managers (Table 1). Action arena #1 was public land owned by the village government and managed by the Fire Care Community. Action arenas #2 and #3 were co-managed land, owned by villagers and managed by farmer groups. Action arenas #4, #5, #6, and #7 were private lands owned and managed by farmer households. The majority of action arenas were on peat with depths ranging from 4.1 to 7.46 m. The majority of action arenas were covered with shrubs and trees with flat topography, except for action arenas #4, #5, and #6, which were farmer's private lands developed into smallholder rubber plantations, and action arena #7, which was a home garden. Action arenas #2 and #3 in particular were post-fire areas with a history of recurring fires. Using the peat map as a reference (Fig. 1), each of the actors developed biophysical interventions, institutional strengthening, and a business model plan in their respective action arena by considering the arena characteristics and sustainable peatland management and development. The biophysical intervention involved constructing canal blocks to rewet peatland; constructing ponds; monitoring dip wells; and planting a combination of trees, multipurpose tree species, or crops. The institutional plan included interventions and facilitation to foster collective action, capacity and knowledge, and the strengthening and formalization of institutions. The community-based business models form the big picture of reconciliation among peatland restoration, fire prevention, and economic development in the form of collective business on agroforestry and ecotourism.

Community groups, who are the main actors in the action arenas, each had different interests in developing their business model. Hence, there were various business model with different mid-term crops and long-term trees species cultivated in each of the action arena. It is the community that collectively decide what kind of business model to be developed and what kind of crops and trees to be cultivated, with the guidance from the research team. Some of the native peat tree species planted were kuras *(Dryobalanops* sp.*)*, swamp meranti *(Shorea* spp.*)*, durian *(Durio zibethinus)*, asam gelugur *(Garcinia atroviridis)*, agarwood *(Aquilaria malaccensis)*, and tampui *(Baccaurea macrocarpa)*. The Fire Care Community in action arena #1 developed their area for nature-based tourism on peatland with constructing fish pond *(embung)* and planting native peat and multipurpose tree species (Fig. 3). The actors in this arena expect nature-based tourism activities, such as fishing and fish production, to be the main attractions and sources of income. While hardwood would not be harvested for its timber, the actors planned to utilize the multipurpose species for their fruit. All action arenas were managed to maintain the water table at 40 cm, referring to the Government Regulation No. 57 Year 2016 on cultivated peatlands, to reduce fire risk and further degradation. As the water table improved in the long-term, only the trees species that may withstand. To this end, the business model can be adapted based on the environmental condition or progress, market, and government policy.

The activity to develop business model and conduct restoration interventions implied cost and benefit-sharing among the actors who managed the action arena and key partners, such as the village government and facilitating organizations (CIFOR and PSB UNRI).

The actors contributed their working time, and facilitating organizations supported the initial investments needed for business model implementation. The benefits will be internally managed by the actors to cover their operational costs for future fire prevention and peatland restoration activities.

3.3. Evaluation of performance and the community-based peatland monitoring system (CO-PROMISE)

To evaluate the outcomes and impacts, the following criteria were used: participation, transparency, knowledge improvement, institutions, and economic and environmental benefits (Fig. 2). At the beginning of PAR, the following aims were envisioned: communities that would not use fire; business models that performed well; Fire Care Communities that operate routinely; improvements in overall performance; strategies formulated; farmer groups established; and reinforcement and support from others. These outcomes would support the overall objective of fire and GHG emission reduction, restored peatland, and sustainable livelihoods. We monitored the institutional and systemic changes through the course of PAR, this includes participant observation in the field activities, focus group discussions, and household and institutional surveys. In exchange for resource support, actors provided in-kind contributions through voluntary work in patrolling, cultivating crops and trees, and maintaining and monitoring action arenas. We recorded a total of 49,499 working hour contributions, which equates to USD 46,908 from 1,237 actors and stakeholders, of which 13% were leaders in discussions, workshops, and related events. Most importantly, the participants contributed 531 ideas for peatland restoration, fire prevention, and alternative livelihood development as a result of engagement in events and discussions. Some of the ideas included partnering with community and corporate groups, water sharing on peatland, and a fire-free village program. In the final household survey involving 110 respondents, nearly 99% of the community stated that they will not use fire despite the revocation of the government's zero-burning instruction. About 65% confirmed interest in employing ecologically friendly land preparation without using fire, for example through manual slashing or manual slashing and supervised application of herbicide. Seventy-three percent of those who actively participated in the PAR process stated their interest in adopting ideas and inputs from discussions. External support and reinforcement were discussed further in below section (see 3.6).

For the business models, we monitored and evaluated their performance by observing the extent of progress and implementation in accordance with the business model canvas and action plan (Table 1). The evaluation is also complemented with monitoring of the biophysical successes using CO-PROMISE. Although all business models were promising on paper, their success relied heavily on the implementation process and extent of commitment, leadership and organization of collective action among actors. Action arenas #2, #4, #1 and #7 were ranked the highest in performance and implementation progress. There was strong collective action and leadership driving their success (Jalil et al., 2021). Driven by a strong motivation, the actor for action arena #2 was more cautious in implementing the action plan as their business model involved co-management of land and there was a time-bound agreement with the landowner. Despite having more members in its group, totaling 21 persons, action arena #2 managed to organize its collective action through transparency, communication, and priority scheduling. They successfully implemented their planting and harvesting plan. They even marketed pineapple through a social networking platform directly to end consumers. They also traditionally processed raw pineapple into sticky cake. In comparison with action arena #3, which has similar characteristics, the actor of action arena #3 demonstrated different levels of performance and progress, primarily influenced by weak leadership and a lack of collective action. After the project ends, the action arenas manager has experimenting with other types of agricultural or food crops on peatland. These experiments were not involving the use of fire in the land preparation stage. They employed manual land preparation which has low impact to the peat soils.

In addition to performance and implementation progress, the biophysical aspect success of the business model was monitored through the participatory monitoring system CO-PROMISE. This system covered water level monitoring and plant and crop inventory and monitoring. The dashboard ensured transparency of the progress of restoration interventions in the action arenas. The water level monitoring system enabled data collection and visualization of groundwater levels in peatlands in combination with supporting data on solar radiation, soil moisture, and peat subsidence. After 15 months of observation of groundwater levels, increases of 5.8–24.07 cm (the mean increase was 12 cm) in action arenas was observed with canal blocking interventions (Tables 2 and 3, Fig. S8). This increase in groundwater levels, combined with a comprehensive approach to fire patrol and interventions under PAR, have contributed to the avoidance of recurring fires, especially in the action arenas. This is aligned with Murdiyarso et al. (2021) findings that indicate that rewetted peat has a 30% less fire risk. We also observed zero fire occurrence in the action arenas in particular and in Dompas Village in general, resulting from the intervention that increase groundwater level (Murdiyarso et al., 2021) and supportive climatic condition, i.

Table 2
Average ground water level increases measured within a 15-month period (March 2019–June 2020).

Action arena	Average ground water level (in cm)		
	Treatment	Control	Rise of ground water level
#1	−99.16	−111.71	12.55
#2	−82.98	−88.93	5.95
#3	−83.28	−96.22	12.94
#4	−100.83	−111.54	10.71
#5	−95.44	−101.25	5.81
#6	−84.05	−108.12	24.07

Table 3
Output and immediate impact of the intervention.

Village	Fire prevention and suppression approach						Peatland restoration approach			
	Burned area 2015 (in ha)	Burned area 2016 (in ha)	Burned area 2017 (in ha)	Burned area 2018 (in ha)	Burned area 2019 (in ha)	Burned area 2020 (in ha)	Rewetting	Revegetation	Revitalization of livelihood	Institutional and knowledge strengthening
Main village (Dompas)	90.63	0	0	0	0	0	• 6 canal blocking • 54 monitoring dip well • Increase of groundwater level by 5.8–24.07 cm • Reduce GHG emission by 10–13 Mg/ha/year • Reduce fire risk	• 1918 trees • 64,772 crops • High survived rate of 72.68% and above	• 7 business model at 11.1 ha and 311 household's homegarden • 1 *embung* (pond) • 42 *perigi* (small water reservoir) • 49,499 working hours contribution	• 1 Forest Farmer Group formalized • 1,237 of Actors and stakeholders participated/ connected • 531 ideas for peatland restoration, fire prevention, of alternative livelihood development • 99% of the community will not use fire • 65% will employ fire-free land preparation • 73% will adopt ideas and inputs from discussions
Other villages (Tanjung Belit, Buruk Bakul, Sejangat, Sukajadi, Sungai Pakning)	347.18	653.63	0	0	0	0	–	–	–	-

e., wet dry season (Table 3). Rewetting the peatland also reduces GHG emissions. Using the Carlson et al. (2015) method, it was estimated that with the use of canal blocking, the action arenas produced 90–125 Mg/ha/year of emissions. This is about 10–13 Mg/ha/year less compared to the control area (i.e., 103-135 Mg/ha/year) (Murdiyarso et al., 2021). This immediate outcome, if maintained, would contribute to the overall goals of the project to reduce fire and emissions and restore degraded peatland.

We also monitored the planted and survived trees and crops using CO-PROMISE (Table 3, Fig. S9–S11). There were 1,198 trees and 64,772 crops planted in action arenas #1 to #7. The species planted in each action arena differed based on the business model implemented. For example, in action arena #1, hardwood and multipurpose tree species were planted, while in action arenas #2 and #3, trees and pineapple were intercropped. Most of the trees and crops were tagged for their geolocation, measured for height and diameter, observed for survival/mortality, and pictured using CO-PROMISE. CO-PROMISE recorded that the survival rate was 72.68% in action arena #1, 99% in action arena #4, and 98.71% in action arena #7. For action arenas #2, #3, #5 and #6, the survival rate of trees and crops was not monitored but for action arenas #2 and #3 it was planned to monitor the harvested fruit crop.

3.4. Institutional strengthening

CIFOR-PSB UNRI strengthened the action arenas' institutions to further reinforce and organize collective action for sustaining fire prevention and peatland restoration efforts beyond the project's duration. This is being carried out through the facilitation of mergers among the actor groups who manage the action arenas to form a Forest Farmer Group. We facilitated the formal establishment, registration and legalization of the groups under the Forest Farmer Group of Dompas Ghedang Cemerlang. The Forest Farmer Group has a shared social capital, vision and mission, a clear management structure, rules and regulations, and a binding agreement. The agreement serves to enable clarity and transparency in operationalization of the institution, including the roles and duties, and cost-benefit sharing. Further institutional strengthening was carried out with a focus on the Fire Care Community Group, a section within the Forest Farmer Group, to support the continuation and improvement of fire prevention efforts. This was done through experience-sharing and joint activities among the Fire Care Community in Dompas, Sungai Pakning, Pakning Asal, Sukajadi, Tanjung Belit, Buruk Bakul and Sejangat. The focus covered strengthening the (a) roles and duties; (b) standard operating procedures for fire control and suppression, and asset management; (c) the work plan and implementation checklist; (d) socialization and recruitment of new members; (e) patrols; (f) construction and maintenance of monitoring canals and wells; and (g) fire alerts. This was expected to contribute to improving their capacity and performance in dealing with the complex problems of forest and land fires, and to attract support from stakeholders to assist with operational needs. CIFOR-PSB UNRI also supported fire patrols and suppression in three villages – Dompas, Pakning Asal, and Sejangat.

3.5. Connecting the dots

The formalization of the Forest Farmer Group has served reinforcement purposes and enabled the group to access assistance from the government, the private sector and CSOs. The establishment of the group was the most common prerequisite for accessing aid and assistance. Further, with a clear vision, mission and activity plan, the group can also attract support from other stakeholders. For stakeholders to be aware of the group's presence, CIFOR-PSB UNRI connected the group with other networks and stakeholders through the facilitation of meetings and events. In total, 1,237 stakeholders participated and engaged in the PAR process. The Forest Farmer Group shared their experience at a subnational-level workshop in Bengkalis Regency on 28–29 August 2019; at a national-level workshop; at a book launch of lessons learned (Purnomo and Puspitaloka, 2020) in Riau Province on October 24, 2019 and Jakarta on January 16, 2020; and at an international event – the Global Landscapes Forum in Bonn, Germany on June 3, 2020. Participation in these events synergized the efforts made in Dompas Village with other stakeholder programs, such as the provincial government's Green Riau initiative, the national government's agenda, international commitments to peatland restoration, and the private sector's sustainability programs. Following this engagement was reinforcement, where the government selected the group to participate in the government's Community Seedling Farm program, which provides seedlings, funding, and capacity building. There was also a commitment made by the local government to allocate village funding to support the group's activities. The private sector in action arenas #1 and #3 also provided support by constructing a field hut, providing fish seedlings for the *embung* (pond), and extending an invitation to join the private sector's Integrated Forestry and Farming System program.

4. Discussion

4.1. The strength of PAR with IAD framing

Sayer and Campbell (2004) outline two main positions of researchers in sustainable development. The first one is positive realism, where the researcher acts as an independent observer so that they can be objective in observing the system. The second one is constructivism, where researchers are part of the system and become more involved. In PAR, the researchers took the constructivism position, and became part of the system and contributed to change. The constructivism approach was beneficial as it allowed us to observe the problem using an insider's perspective and provided the advantage of being more closely connected to local actors. We were able to analyze the critical points necessary to catalyze social transformation to achieve the overall goals of fire prevention, peatland restoration and livelihood improvement. The approach is not without its limitations, but it was suitable with regard to the expected goals. The case in Dompas Village and the satellite villages nearby is a model to learn from the implementation of the IAD framework and PAR process. Although the findings were site- or locally specific, we responded to this problem by connecting the work

with the world outside – hence the findings can be benchmarked and the process adapted for other cases with similar contexts.

4.2. Community-based peatland restoration and fire prevention approach

To drive wider community participation, peatland restoration and fire prevention should be designed to include business model development in its approach. Business model developed in PAR process is an example of GoI (Government of Indonesia) multi-use forestry initiative on the ground at the community level. The process in developing business influences social learning among the communities in Dompas Village, which encourages them to practice adaptive management in the process and contribute more significantly to preventing fire, restoring peatland, and transitioning to more peat-friendly cultivation practices. In addition, CO-PROMISE enables the community to actively participate in monitoring the restoration and business model progress, foster learning process, and support informed-decision when any corrective measures needed. The community-based restoration approach operates on a small scale and embodies the bottom-up approach, where the community can test and monitor their ideas, actively involve themselves, and learn to protect and restore the peatland. This may not be possible if the intervention were top-down and carried out on a large scale where only actors with substantial capital could play a critical role.

PAR process in Dompas Village enable the acceleration of fire prevention on the ground, when many of local efforts were leaning towards fire suppression. In one of the phases, the community discussing ways to prepare land without using fire and experimenting with manual slashing and supervised application of herbicide. The community become aware of these alternative and familiar with restoration approach, such as canal blocking. The canal blocking and cultivation of trees and crops, monitored through CO-PROMISE, can reduce emission from peat decomposition and sequester carbon at a small scale. CO-PROMISE data shown the canal blocking in Dompas action arena has raised the groundwater level in a long period of time, including during the dry season, and reduced emissions from peat decomposition (Murdiyarso et al., 2021). Connecting the dots of similar efforts can contribute to the GoI target in reducing greenhouse gasses emission in FOLU (Forests and Other Land Uses) Net Sink 2030 initiative.

4.3. Collective action and local leadership to catalyze change

Peatland restoration is a way to recover the conditions of degraded peatland to minimize fire risk and reduce emissions. It also has to be understood as a common goal of the community and stakeholders nearby and beyond the restoration site. It is therefore urgent to establish a joint vision and collective action. Seven business models and action arenas were developed and implemented that demonstrate concrete behavior changes in communities toward eco-friendly business and land management. The research methods and outcomes of this PAR have been communicated to governments, scientific organizations and CSOs at the village, regency, province and national levels. Stakeholders have shown interest in, and appreciate the work. Most importantly, the community has shown interest in, and willingness to adopt the ideas and lessons developed through the course of the research and beyond. The participation of communities is key because they are the agents of change. Even though they matter individually, if they organize themselves with clear rules-in-use or institutions, then larger social transformations can be catalyzed and achieved. This is led by local champions and their leadership can influence others' commitment to, and enthusiasm and motivation for investing in fire prevention, peatland restoration and livelihood improvement. After all, the communities are economically rational beings. Efforts therefore must be designed to provide benefit. We found that the business model canvas (Osterwalder and Pigneur, 2010) is a useful tool to help communities reach agreement on what values should be proposed and what the resources, strategies and target markets are.

4.4. Demand for tangible outcomes and meaningful impacts

Stakeholders demand research that delivers real outcomes and impacts. Changes in the way we manage natural resources that are influenced and generated through research outcomes and impacts are needed. Otherwise, fire and haze, as well as deforestation and environmental degradation, will continue to occur. Research should not only produce reports and publications, but also provide scientific and evidence-based information to catalyze and generate transformative changes and impacts on the ground. Research that emphasizes the participation of stakeholders and communities and is impact-oriented is needed to foster real change. PAR is a transdisciplinary approach, where various scientific disciplines ranging from biology, sociology, economics, forestry and agribusiness meet local and traditional wisdom. It enriches research approaches in environmental and natural resource management in the context of fire prevention and peatland restoration that deals with ecological and socioeconomic complexity. It needs intensive interaction with communities, CSOs, policymakers and the business sector. When starting PAR, clear demand from the local community on the intervention is a mandatory requirement. Understanding local needs and stakeholders' aspirations are critical requirements for a PAR process. Demand is not only interpreted as consent or interest, but as a commitment to take genuine action to ensure returns on efforts and monetary 'investments'. Likewise, political support from local governments is necessary to sustain efforts beyond a project's duration. This could be in the form of participation, the provision of facilities, or the willingness to align with similar existing programs. Although PAR requires more time, resources and costs compared to conventional research and comes with limitations, the benefits and impacts are concrete, immediate, and outweigh the costs. When change is really needed there is a price that we have to pay.

5. Conclusions

Indonesia's fire prevention and peatland restoration approach were designed to serve multiple purposes and benefits for the ecosystem and community due to the immense challenges it faced. Many fire prevention and peatland restoration initiatives on the ground were not well structured in terms of process, nor well documented and evaluated for their progress, outputs, and immediate impacts. There was often a lack of scientific and evidence-based information to support decision-making processes, management, conceptual frameworks and implementation steps. This paper sets out an example of utilizing the PAR approach with IAD framing to embrace participatory processes to foster knowledge exchange driven by science and evidence that facilitates adaptive management. Our research indicated, first, that the PAR with IAD framing can catalyze change on the ground in the case of fire prevention and livelihood improvements in Dompas, Riau. Second, we identified four critical points necessary for success: (a) clear demand from the local community for the intervention; (b) adequate political support from local governments; (c) community participation, leadership, social capital, and strength of local institutions; and (d) profitable business models that support the transition to sustainable livelihoods on peatlands with clarity and transparency on cost-benefit sharing. Furthermore, being explicit with the biophysical and socioeconomic variables, action arenas, outcomes, and impacts make interventions more systematic and scientifically reliable.

CRediT authorship contribution statement

Herry Purnomo: Conceptualization, Funding acquisition, Investigation, Supervision, Writing – original draft. **Dyah Puspitaloka:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – review & editing. **Beni Okarda:** Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing – review & editing. **Agus Andrianto:** Conceptualization, Investigation, Methodology, Writing – review & editing. **Nurul Qomar:** Writing – review & editing. **Sigit Sutikno:** Writing – review & editing. **Ahmad Muhammad:** Writing – review & editing. **Imam Basuki:** Investigation, Methodology, Writing – review & editing. **Ashaluddin Jalil:** Writing – review & editing. **Yesi:** Writing – review & editing, Writing – review & editing. **Pandam Prasetyo:** Writing – review & editing. **Tarsono:** Writing – review & editing, Writing – review & editing. **Zulkardi:** Writing – review & editing, Writing – review & editing. **Sonya D. Kusumadewi:** Writing – review & editing. **Heru Komarudin:** Writing – review & editing. **Ahmad Dermawan:** Writing – review & editing. **Michael A. Brady:** Writing – review & editing.

Declaration of competing interest

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

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Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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