Community perceptions of peat rewetting in Tumbang Nusa Village, Indonesia

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SUMMARY

Indonesia is committed to rewetting peatlands to reduce the risk of fires and to decrease national greenhouse gas emissions. The three main approaches currently being implemented for rewetting peatlands in Indonesia are: 1) installing dams in drainage canals - "canal blocking"; 2) filling in drainage canals - "backfilling"; and 3) drilling wells to access water to fight fires - "deep wells". Tumbang Nusa in Central Kalimantan was chosen in 2020 as a pilot village to trial fire management through rewetting, although some engineering and logistical questions remain. Peatland rewetting is a complex process, and it is essential to determine public support as well as the potential for communities to live and work with rewet peat landscapes. Community attitudes to rewetting and their involvement in the process are not well understood. This article reports on 20 interviews conducted with villagers in Tumbang Nusa about their perceptions of rewetting. It identifies that the general attitude to rewetting is positive, but there is confusion and a lack of involvement with regard to where deep wells have been drilled and where canal blocks are located, as well as how they work and can be used. Villagers are concerned about their livelihoods and the impacts of fire. To support communities where rewetting will occur, careful management of the physical processes is needed, but even more important is the need for greater involvement of local communities in actively developing possibilities for their own futures on rewet peat.

KEY WORDS: climate change, fire, greenhouse gas emissions, livelihoods, peatland restoration, social barriers

INTRODUCTION

Annually recurring forest and land fires in Indonesia have become a chronic problem with devastating environmental, economic and social impacts. Despite bans on the use of fire in preparing land for crops or agriculture, it is still a significant cause of peatland loss and degradation (Saharjo 2007, Glauber *et al.* 2016, Dohong 2019). During the El Niño dry season of 2015, fires occurred across Indonesia from June to November, burning 2.6 million hectares of land, and thick smoke haze from incomplete combustion of peat caused an estimated economic loss of at least US $ 16.1 billion (Glauber *et al.* 2016, BRG 2019). In 2019, Indonesia again suffered extensive peat fires across eight provinces, with an estimated economic loss of US $ 5.2 billion (World Bank 2019). The provinces that suffered most from these fires were Central and West Kalimantan where it was estimated that 620,201 ha of land burned, of which 44 % was peatland (World Bank 2019).

Peatlands have been drained to convert peat swamp forest to agricultural and forestry land uses such as oil palm and *Acacia* plantations, rice fields and smallholdings (Miettinen & Liew 2010). Drainage is implemented by constructing channels that range from small, hand dug ditches (Figure 1) to major canals dug with heavy machinery up to 25 m wide and 4 m deep (Page *et al.* 2009). The canals are also commonly used to transport agricultural and forest products by boat or floating rafts (Suryadiputra *et al.* 2005, Dohong *et al.* 2018, Ward *et al.* 2021). The canals have become integral transport networks for the communities living in their vicinity (Page *et al.* 2009). Their existence expands access to land in this region, where rivers have traditionally played the role of roads.

Drainage canals lower the water table in the surrounding peat, which increases peat drying and, consequently, the risk of peat fires (Suryadiputra *et al.* 2005, Turetsky *et al.* 2015). Despite efforts to restrict the use of fire to clear peatland, fires can still

Figure 1. Small canals draining peatland in Tumbang Nusa.

occur through illicit uses for agriculture, or even accidentally during cooking and hunting. When a surface fire moves into the peat it can be extremely difficult to extinguish (Goldstein *et al.* 2020), often continuing to burn until the water table rises after arrival of the wet season rains. Drainage also enables biological oxidation of the dry peat, which generates greenhouse gas emissions that can exceed those of fire (Hooijer *et al.* 2014, Miettinen *et al.* 2017). Drained peat provides an aerobic substrate that can support the growth of dryland plant species that are not able to survive under the anaerobic conditions of undrained, or rewet, peatlands. Therefore, drainage improves the growing conditions for dryland-adapted plants and deteriorates the conditions for wetland-adapted plants. While economic development on peatlands was previously a national priority in Indonesia, more recently the negative effect on environmental values has been recognised and the tension between achieving outcomes that are both economically and environmentally sustainable is an ongoing challenge (Harrison *et al.* 2020). Rewetting is intended to address negative environmental effects, but there is a lack of evidence on community attitudes to rewetting, and while these data can be difficult to collect, they could make an important contribution to understanding how changes might be accepted or rejected and what benefits, burdens, constraints and opportunities exist for locals and might be relevant more broadly. Our article contributes this important early-stage assessment of community perceptions of, and engagement in, rewetting.

Efforts to rewet

Since the early 1990s (starting with Presidential Decree No. 32/1990 on the management of protected areas), the Indonesian Government has committed to a number of policies directed at sustainable development of peatlands, including the suspension of licenses for clearing peatlands and their gradual restoration. In 2016, the peatland restoration agency "BRG" (*Badan Restorasi Gambut*) was established with the goal to restore two million hectares of peatland (Giesen 2018). BRG focuses on the '3 Rs for restoration' - Rewetting, Revegetation and Revitalisation of Livelihoods (BRG 2018). Peatland rewetting aims to restore the natural hydrological functioning of peatland, particularly with respect to peat wetness and moisture, and thereby reverse the negative effects of drainage (Dohong *et al.* 2017a, Dohong *et al.* 2017b). The key objective is to raise the water table to as close to the surface as possible, such that it reduces fire, oxidation and the associated greenhouse gas emissions and subsidence, and at the same time restores conditions conducive to vegetation re-establishment where appropriate (Jauhiainen *et al.* 2008, Page *et al.* 2009, Günther *et al.* 2020).

The three main approaches currently being implemented for rewetting peatlands in Indonesia are: "canal blocking" (*sekat kanal*); "backfilling" (*timbun kanal*); and 3) "deep wells" (*sumur bor*). Canal blocking involves construction of a canal block or dam to act as a physical barrier to prevent or reduce the outflow of water through the canal (see Figure 2), thereby raising the water table in the area upstream

Figure 2. Installation of a canal block in Tumbang Nusa.

(Suryadiputra *et al.* 2005, Dohong *et al.* 2018). There are many canal block designs, some that enable passage by boat and others that do not (Ward *et al.* 2021). Canal backfilling uses peat, woody debris or other locally available materials to fill in the canal. Although this strategy has not yet blocked canals completely, it can slow the flow of water, reduce canal depth, and encourage sedimentation, thereby reducing drainage of water out of the canal and improving water retention in the surrounding peat (Applegate *et al.* 2012, Dohong *et al.* 2017b, Dohong *et al.* 2018). Often a combination of dams and backfilling is used. Deep wells are bore pipes inserted into an aquifer (in this region up to 20 m) below the peat, from which groundwater can be pumped up and sprayed onto the surrounding landscape both as a (limited) fire prevention strategy and for fire-fighting. However, this approach does not contribute to permanently raising the water table (Dohong *et al.* 2017b). In this article we use the term 'rewetting' to include all three approaches (canal blocking, canal backfilling and deep wells).

By 2020, the infrastructure built by BRG and partner institutions for rewetting peatlands across Indonesia included more than 15,000 deep wells, 7,000 canal blocks and 400 backfilled canals (BRG 2020). In addition, BRG installed 154 water level monitoring devices in selected locations between 2017 and 2018 (BRG 2020). It is important to note that the figures for infrastructure installed may differ from the infrastructure that is fully functional due to components breaking or being damaged.

Constraints on rewetting

Concern about livelihoods is a key aspect of perceptions about rewetting because rewetting may reduce potential earnings from dryland agricultural crops such as oil palm. Tumbang Nusa can already be considered a mixed livelihood village, and the residents we spoke to are open to considering and trialling alternative options for food and income generation such as aquaculture, different fruits or vegetables, and value-added products (e.g., smoked fish and handicrafts). Rewetting processes are ongoing and the water table will aways be dynamic, so further understanding of opportunities for flexibly responding to changes as they occur (e.g., if the area is unexpectedly flooded) is still needed. At present, new livelihood options on rewet peat are less financially appealing than oil palm production, leading to a tension within national efforts to restore peatlands and by the same token increase food production and GDP, as well as local tensions between rewetting efforts and further drainage.

Opportunities to enhance rewetting

The examination of community attitudes and involvement in rewetting in Indonesia is only just beginning (Ward *et al.* 2021). In their assessment of 181 household questionnaires, Ward *et al.* (2021) found that most of the community would accept canal blocking on their land because of perceptions it would reduce fire risk and have no negative consequences. BRG conducted a perception survey on their efforts at peatland restoration with 3,802 respondents in ten districts/cities (including the district where Tumbang Nusa is located) and determined a rating of 'good' (BRG 2019). Nevertheless, it is unlikely that the effects of peatland rewetting and restoration strategies on communities will be understood until the effects of rewetting and restoration on the ground are manifest.

Rewetting is a complex technical and social transformation (Uda *et al.* 2020a). Community engagement is essential if restoration is to be achieved successfully in terms of environmental *and* socio-economic outcomes (Ward *et al.* 2021); and needs to be documented, evaluated and used to inform further implementation. This requires a careful balance of community guidance (to increase awareness and engagement in trialling different strategies) and support (in exploiting opportunities for communities to design their own new ways to live with rewet landscapes) (Fleming *et al*. 2021). Top-down policy and governance arrangements must articulate actively with local communities in helping to support and scale out successful bottom-up changes (Januar *et al.* 2021). Yet even though all adoption and policy literature across many disciplines (environmental management, international development, ecological restoration, etc.) suggests that, for behaviour change to take place, stakeholders need to be active participants in planning, implementation, evaluation and adaptive learning, rewetting efforts to date generally lack 'village voices' reporting community experiences (Ward *et al.* 2020), (Butler *et al.* 2014, Bammer 2013, Reed 2008).

In other words, peatland restoration is complex and multi-faceted (Figure 3) but an important first step towards success involves ensuring that local communities have a shared vision for the process, particularly the rewetting stage, which is the stage that is most likely to impinge on their livelihoods. Perceptions provide important insights towards understanding how villagers may be affected by rewetting and where opportunities to improve outcomes for both the environment and local livelihoods might arise. Thus, the objective of our study was to understand how villagers in Tumbang Nusa perceive rewetting.

METHODS

Conceptual framework and methodology

To assess awareness of peat, peat use, access to peat, sustainability (fire and rewetting) and adaptation to change (potential livelihoods on rewet peat) we use interviews and content analysis following constructivist grounded theory (Charmaz 2006). For early insights into system changes and to provide a benchmark to revisit to determine whether community perceptions, learning and innovation are having a positive effect over time, qualitative in-depth interviews provide a useful and valid research method. Using constructivist grounded theory foregrounds both the participants' experiences, attitudes and expectations and how these relate, interact and contribute to (construct) broader social perceptions (Charmaz 2006). This helps to address bigger-picture questions of how technical interventions in system change (rewetting) might be enhanced or constrained by the social context.

Location

Tumbang Nusa is located around 100 km inland and at an altitude of 10–50 metres above sea level (BPS 2020), in Jabiren Raya Subdistrict, Pulang Pisau Regency, Central Kalimantan (see Figure 4). Geographically, Tumbang Nusa Village covers a total area of approximately 200 km^2 within the Kahayan hydrological catchment, and is traversed by both the Kahayan River and the Trans Kalimantan highway (BRG 2018). The population is 962 people (492 male, 470 female) making up 286 households (BRG 2018). As a mixed economy village with fishing and non-agricultural economic activities, Tumbang Nusa differs significantly from many other communities in Central Kalimantan. Most of the inhabitants are fishermen, while some work as traders or in tree nurseries and others breed goats, cows or swallows (for their nests).

Nearly 90 % of the village area is peatland with a peat layer 2–8 metres deep (BRG 2018). Most of the peatland is drained but not currently actively managed, and very prone to burning during the dry season. The people living around this peatland area do not know exactly who owns it, because many landowners live outside the village. When there was a severe fire in 2015, almost 50 % of the area was burned, including community-owned land under plantation crops (BRG 2018).

Tumbang Nusa was selected in 2020 as one of the Central Kalimantan pilot villages for fire management. It was also designated by BRG as a "Peat Care Village" (*Desa Peduli Gambut*), which involved formation of the "Fire Care Society" (MPA;

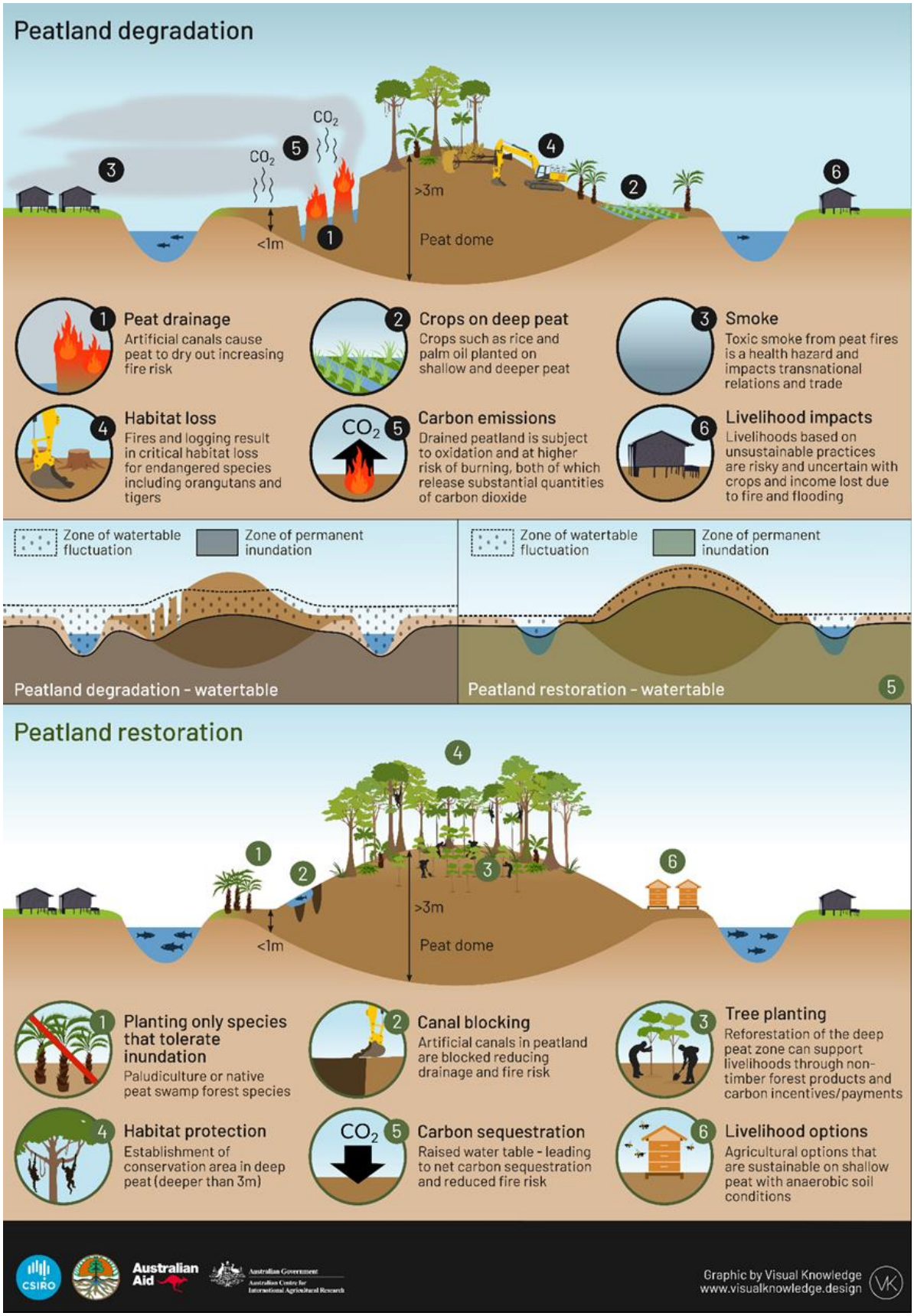

Figure 3. A vision for peatland rewetting and restoration, from Fleming *et al.* (2021). To work effectively within this level of complexity there is a need to understand the issues at local (villager) level and to work with locals and local organisations to achieve desired visions for change.

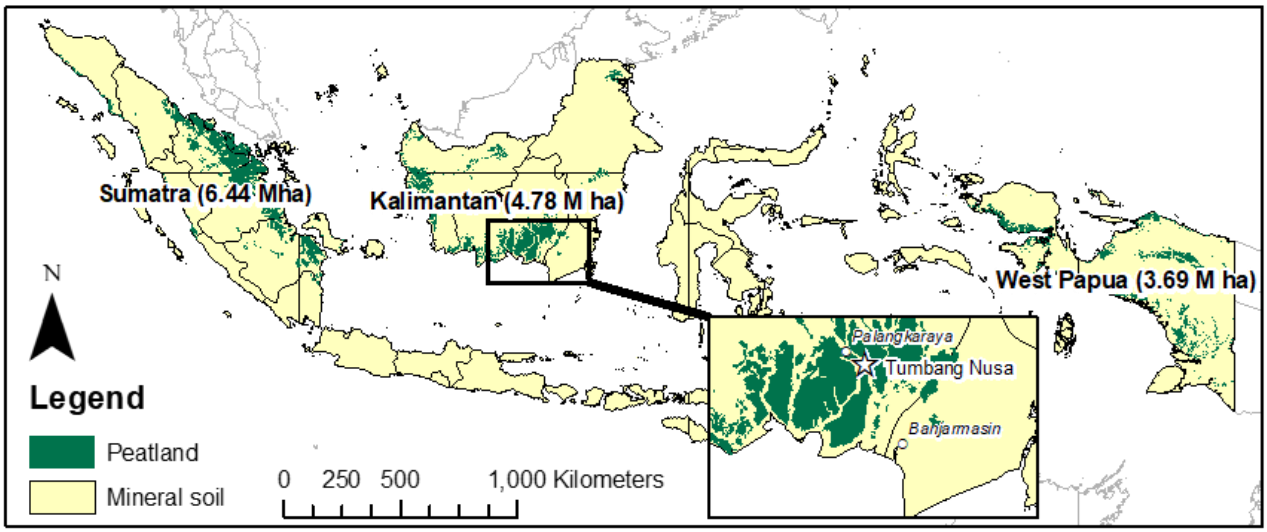

Figure 4. Map of peatland areas in Indonesia and the location of the study village, Tumbang Nusa, in Central Kalimantan. Peatland extent is based on the 2019 Ministry of Agriculture mapping, available at www.globalforestwatch.org.

Masyarakat Peduli Api), a community group established to aid in fire prevention. The roles of the MPA were to act as a source of information to the village community about fires, to help raise awareness of strategies to prevent fire, and to train the community in how to respond to fires (Nurjanah *et al.* 2021). Now there are around eight canal blocks in Tumbang Nusa, and 250 deep wells have been drilled to support rewetting and fire-fighting efforts (see Figure 5). The arrangement of deep wells in rows extending from the road suggests that ease of installation was a strong driver of placement. These wells can serve only a very limited area, so rewetting (and fire-fighting) remains difficult in these locations.

Interview process

To gauge community perceptions of rewetting in Tumbang Nusa and, therefore, the potential for success of rewetting strategies, interviews were conducted by a local NGO, the Tambuhak Sinta Foundation (YTS; *Yayasan Tambuhak Sinta*), which has had a long involvement with the project team. The remit of YTS is to help small communities and local governments work together in a productive, sustainable and equitable way. The process for organising interviews involved several initial coordination meetings with the village head in Tumbang Nusa to inform her about the objectives of the project and to identify potential interviewees. The village head recommended that the team should liaise with the head of the MPA as a key source of information and knowledge about the peat fire management programmes in the village.

In total, 20 interviews were conducted in August and September 2020. Ethics approval was received prior to engagement and included informed consent. Participants were selected during visits to the local village, according to their time availability and interest. Recruitment was purposefully targeted to encompass much of the variation in the village in terms of gender split and age range, and the participants were ten men and ten women ranging in age from 24 to 59 years. The participants included some farmers and some with other occupations (labourers, stallholders, plant nursery workers engaged in raising seedlings for revegetation programmes). A number of participants had multiple and seasonal occupations which changed frequently, and some held official positions relating to fire control or rewetting which meant they had a good oversight of village activities. The interviews were considerably facilitated by being conducted in the local language (Bahasa Indonesia) by one interviewer and one note-taker from YTS, who were familiar to many in the community from previous engagements and had spent extended time in the village. An interview normally took 30 minutes to one hour and was recorded with audio recording and notes, then transcribed and translated by YTS. Open-ended questions that were asked of the respondents are shown in Table 1.

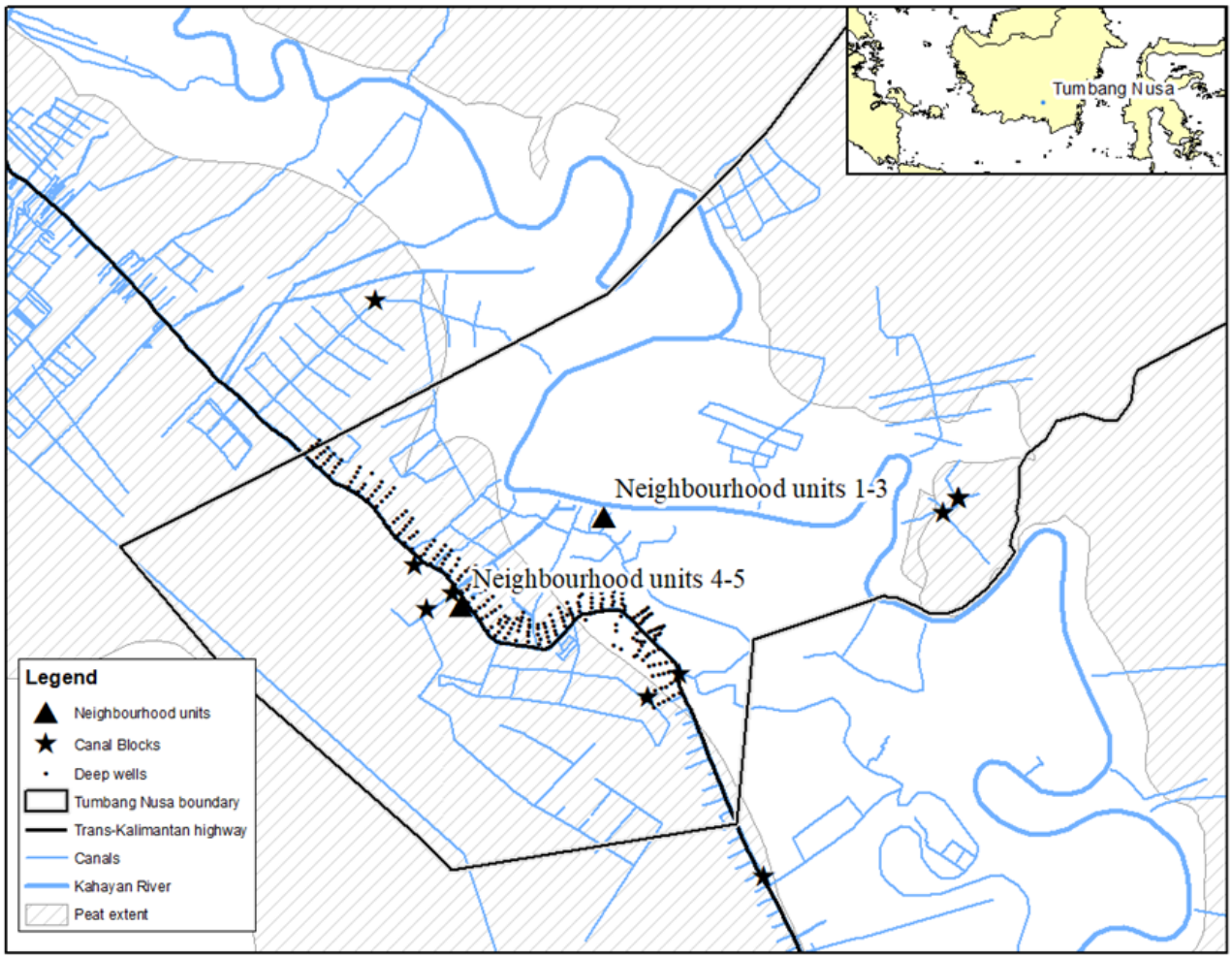

Figure 5. Canals and rewetting infrastructure at Tumbang Nusa. Village and peat boundaries are approximate. Peatland extent is based on the 2019 Ministry of Agriculture mapping (available at: www.globalforestwatch.org), canals and deep well locations are from the BRG PRIMS system (available at: en.prims.brg.go.id, accessed 10 May 2021), and canal block locations were identified by the project team on the ground.

Limitations

Given that our study aimed to understand perceptions, there were no right or wrong answers, and the interviews aimed to be discussions of early perceptions of rewetting rather than merely lists of questions. Moreover, we report results from only one village which we recognise has a history of engagement with research and government, and feel this adds to the villagers' ability to reflect and comment on the process. The context of Tumbang Nusa differs from that of other villages insofar as it sits beside a river, so the context may not be generally transferable. However, we feel that the small sample size was suited to the narrow scope of this study, the analysis was in-depth, and we were reaching saturation in the responses. Sim *et al.* (2018) noted that sample sizes as low as 12 may be sufficient for qualitative research when additional data collection is not adding further insight. Our research does not claim to be representative, but rather to highlight important insights about the lack of community awareness and involvement in relation to rewetting. As many of the authors are not native to or resident in Indonesia, we were also limited by factors such as geographical distance, access to the village and language ability, which made us reliant on local project team members to collect and translate data. This is both a limitation and a strength because the local project team were familiar with language, culture, practices, the area, past projects and local history so were able to collect data relatively easily (in local dialects) and help interpret results. We also note that this article provides a qualitative assessment of community perceptions of rewetting, and our recommendations for potential livelihood options are subjective and require further testing. Understanding

Table 1. Questions asked of respondents about their peat, rewetting and livelihoods (text in brackets was used to prompt if required).

Focus	Questions
Peat characteristics	• What sort of peat is in the village? (what area, deep or shallow?) • How is the peat used? (e.g., for growing crops)
Access	• Are there rules on how it is used? (who can access it?) • Is the peat open to everyone? Does gender affect the use/access? • Is there or has there ever been any conflict over how the peat is used? (e.g., outsiders accessing it)
Fire	• Have there been any peat fire that you are aware of? If yes, how did it start, what happened next? • What would happen if there was a fire? (prompt for response and impact)
Use and value	• Does the use of peat change with the seasons? (is a particular time of year busier?) • Is peat important for your livelihood? If yes, how important (rank out of 5). • Is peat important for anything else? (e.g., biodiversity)
Rewetting	• Has any of the peat been rewet? If no, do you know of any plan to rewet? • What is your opinion of rewetting? (prompt if heard of deep wells and/or canals)
Adapting to change	• What would change for you if there was no peat or you couldn't use it at all? • What would help you (or other people in your community) to improve your livelihood? • Are there any problems with how the peat is used currently? Or are there any reasons why you have not utilised peat at the moment? • Are there any opportunities regarding how peat could be used?

the rewetting process in terms of both technical and social processes is an important area for further work as the effects become more manifest.

Analysis

The interview data were analysed using NVIVO 12 (QSR software). The interviews were coded for themes (Table 2). Codes were constructed from the data, following methods of inductive grounded theory (Fleming *et al.* 2019), and organised around the themes of fire, rewetting, peat uses and descriptions, and current livelihood options and opportunities. Constructivist grounded theory pays close attention to language use and context and iteratively builds up themes from the data, checking each new idea against the broader source material and exploring the similarities and differences between individual and social perceptions (Charmaz 2006). It also recognises the researcher as part of the process of data collection, treating observations, participant interactions and reflections as part of the process of developing insight, so project team discussions were important to check interpretations and understand context. Reflecting on the interactions of participants with the interviewers, we feel that they were sufficiently comfortable to mention their lack of knowledge about rewetting and their powerlessness in identifying livelihood options, and were well placed to comment given they had a history of engagement efforts in Tumbang Nusa to reflect upon.

RESULTS

Although 15 participants had generally positive attitudes to rewetting because the need to rehabilitate the peatland and reduce fires was recognised as a significant problem, this approval was largely theoretical because few participants had any understanding of the likely effects of rewetting in practice or direct experience of the result. Thus, there was a disconnect between perceptions of rewetting and of the results on the ground. The remaining five participants were unsure whether rewetting was good because they did not know enough about it, or because the different strategies had different levels of effectiveness. There appeared to be little appreciation of how fully rewet peat might limit the community's

Table 2. Coding of the interviews for themes, following methods from Fleming *et al*. (2019).

Theme	Code (number of occurrences)
Fire	Effects of peat fire (21) Burning ban (9) Description of past fire (26) Fire breaks (1)
Livelihood strategies	Rice (4) Rubber (50) Oil palm (8) Foraging (25) Fishing (29) Pineapples (10) Sengon (4) Fruits including rambutan (14) Vegetables (7) Fuel (1) Hunting (1) Move location (1) Rattan (4) Peat for nursery (40) Purun (6) Selling peat (6) Opportunities (25) Building (1)
Peat uses and descriptions	Seasonal use (21) Previously burnt peat (6) Peat infertility (25) Private ownership (4) Gender and access (15) Open access (14) Fire impact on biodiversity (5) Biodiversity (4) Conflicts (6) Discusses deep peat (17) Discusses shallow peat (12) Ranking of importance (20)
Rewetting	Discusses rewetting (28) Discusses canal blocking (10) Positive about rewetting (15) Discusses boreholes (21) Unsure (5)

ability to use it, even though peatland was seen as less useful when flooded in the rainy season. Wet peat was perceived to be more difficult to work with and participants felt they did not have the right knowledge to utilise it. Indigenous communities have a longer history of working with wet peat, mainly for fishing, but the knowledge may not always be shared.

Barriers to rewetting

Barriers to rewetting were lack of awareness and community involvement, particularly for canal blocking, as local people were largely unaware of or uninvolved in canal blocking. Even the deep wells were not widely known about and their function (or lack thereof) in rewetting was also not well understood. Villagers were supportive of rewetting to fight fires and aid conservation/restoration in conceptual terms, but might not be positive in practice as they were not sufficiently involved in placement, implementation or maintenance and had not seen longer-term outcomes. Participants talked about the lack of socialisation to explain about, and include villagers in, the rewetting process and how to respond if there was a fire. Quoting from Interview 12:

"The MPA is good, especially if they can put out the fire faster - as soon as it happens, but I never get involved with this activity because there has been no socialisation for any meeting".

In relation to the canal blocks, there was a lack of awareness about how they are built and whether there is potential for the community to use them or be involved in actively maintaining them. Different participants described the dams as being made of concrete, wood and soil bags. It is unclear from the interviews how effective the dams will be in effecting rewetting, whether they will degrade, or if there is any possibility they will be damaged by (insider or outsider) villagers wanting to access peatland. This is because general awareness of the dams was very low, and few participants knew where they were located. To successfully rewet the surrounding peatland, canal blocks require regular maintenance, which is ideally achieved by including local people in their construction. However, the responses indicated that there are few canals around the village and ongoing maintenance of the canal blocks is not currently a local responsibility.

Opportunities

Fishing is a key opportunity identified by most (17) respondents. More rewetting was linked to perceptions of more access to fishing, and this was another factor in favourable perceptions of rewetting. The expansion of fishing was seen as a promising opportunity although it required support in the form of resources for fish cages, nets and making new ponds, plus training:

"There needs to be support and assistance for community livelihoods such as fish processing and making fish products, e.g., fish crackers (training, equipment and marketing)" (Interview 16).

Peat was ranked very highly in terms of importance for generating a livelihood (60 % of respondents rated it as 1 or 2 out of 5) and most participants were open to new opportunities for livelihoods on rewet peat, although they saw this as being driven by external experts or government rather than by innovation within the community, possibly because this village has been a focus of livelihood projects in the past so villagers are more likely to expect help for new initiatives like using rattan. Quotes include:

"Maybe we need socialisation from the government or the peat experts on how to utilise the peat to improve our livelihood activities and provide income to the community" (Interview 10);

"It needs support from the government and the experts who know what livelihood activity is suitable to be developed and valuable enough so the community will not have economic difficulty" (Interview 13);

"Meanwhile, there is no opportunity to use peat, unless research is conducted by a peat expert". (Interview 15); and

"It is actually quite difficult to depend on peatland for your livelihood, especially rubber tapping because the price decreased. Training and material support to process rattans - this can be an additional livelihood to add income for the community since the price of rattan mats (*lampit*) is quite high" (Interview 10).

Other livelihoods, in order of mentions and whether they were perceived by interviewees as having economic potential, are shown in Table 3. Effects and concerns of Covid-19 were also highlighted as reasons that the community needed help to improve their livelihood options.

Table 3. Community perceptions of the viability of different livelihood options, along with compatibility and sustainability ratings for use on peatland. Compatibility ratings: incompatible (*); compatible with water table < 40 cm below the surface (**); compatible with fully rewet peat (***). Sustainability ratings: leading to rapid loss of peat (*); slower peat loss due to oxidation (**); minimal peat loss (***). Compatibility and sustainability ratings are based on the authors' own observations and opinion. Note that livelihood sources mentioned only once by interviewees (n = 1) are not included.

Livelihood options	Perception of viability	Compatibility with rewet peat	Sustainability
Fishing (n = 17)	Positive, with training and support for supplies	***	***
Foraging for herbs, plants, honey (n = 17)	Positive, with reduced fire	***	***
Rubber (n = 17)	Positive with market improvements, negative without	*	*
Peat as a plant/nursery medium (n = 16)	Positive	**	*
Tree fruits (including rambutan and durian, n = 14)	Positive	**	**
Oil palm (n = 7)	Positive	*	*
Vegetables (n = 7)	Mixed success	** (depending on type)	**
Pineapples (n = 7)	Mostly positive	**	**
Selling peat (n = 6)	Historical, not practised currently	***	*
Rattan (n = 4)	Positive with training	***	***
Rice (n = 4)	Negative related to burning ban	**	**
Sengon (only grows on shallow peat, up to 1m) (n = 4)	Positive if not allowed to grow too big	*	*
Purun (n = 2)	Positive with marketing support	***	***

Perceptions of fire

Fire is a recognised problem for the community. Villagers are afraid of being blamed for starting fires and have changed their practices in response to the fire ban, especially regarding lighting fires to prepare peatland for growing rice. Fire is recognised as a health hazard, causing coughs and headaches, especially for the very young and very old as well as those who are sensitive to respiratory stress:

"When the fire happens, even if it is extinguished, the peat will keep producing smoke that will disturb your breathing, cause breathlessness, and greatly affect toddlers and the elderly, and the livelihood will become even more difficult due to the thick haze" (Interview 12).

Fire haze reduces the ability of local people to forage and do some kinds of work. Everyone gets involved in fighting fires to protect their land. Villagers can cut their own drains to access water for fire-fighting, although this is technique is only suitable in the short term as it can contribute to drying and can make the peat more fire-prone in the future:

"Villagers will make small drainage / small canals on their own land so the fire will not reach and burn the community lands" (Interview 3).

One respondent talked about the causes of fire but there seemed to be low general awareness of how fires started, and most interviewees stated that it was outsiders who started fires. This is likely to be due to the risk of penalty because fire is prohibited. It was noted that awareness and personal responsibility for not lighting fires should increase. The issue of accidental fires caused by dropped cigarette butts or making small fires to repel mosquitos while fishing was raised by a small number of respondents as being under-recognised. Other quotes include:

"From the explanation that I heard, the fires started from the fishing activities of people who smoke cigarettes and throw away the butts carelessly in the dry season. It is always this story that I heard, but I do not know if it is true and I'm just guessing" (Interview 12); and

"Public awareness is important to extinguish fires, not only the responsibility of the Fire Care Community" (Interview 20).

After a fire, the peat is often abandoned and not used. Support to plant and rehabilitate these areas is needed. Respondents noted that healthy peatland is highly biodiverse and even provides opportunities for deer hunting:

"I have ideas about how to use the burned peatland located at the entrance to the village, but I do not have the capital and capacity to manage it. I think the area can be used for tree planting / revegetation and managed by the community, government and other parties working together" (Interview 7).

Gender

Peatlands can be accessed by anyone. Gender is not a factor in using peatland, although different genders tend to do different work - for example, men are more likely to labour and fish and women to forage, work in the plant nursery or process fish and reeds into other products. Some quotes demonstrate this:

"To buy peat (wages for looking for peat) is IDR 12,000 per sack (size 50 kg) and this is done by men. The fee for filling polybags (size 8 × 13 cm at a price of IDR 30,000 per kg) is IDR 50,000 per 1,000 polybags while the wage for planting seeds in polybags is IDR 50,000 per day and this is done by women" (Interview 20); and

"Fishing is done by both men and women, but mostly by men. Specifically for fishing with a tool called a "stake line" (*banjur*), this is carried out by women. Communities have made fish floss, salted fish and fish crackers" (Interview 17).

Peatland ownership is usually communal and hereditary (it was unclear from the interviews how gender influences land ownership). Some of the peat is privately owned. Rules around ownership and access are communicated verbally and there have been only minor conflicts over boundaries which have been quickly resolved.

DISCUSSION

The effects of fire were deeply felt by the villagers we interviewed in terms of impacts on their health and ability to work, environment, and risk of fines. Fire is also recognised in other studies as a significant concern for villagers, who are committed to reducing burning despite the ways in which non-burning reduces their capacity to subsist, with rice growing typically no longer possible (Greenhill *et al.* 2020). Whilst burning occurred frequently in the recent past (e.g., Rohadi (2017) reported that around half of community members were still burning), government restrictions and enforcement of non-burning has resulted in zero reports of burning although reporting one's own illegal activity is understandably unlikely. However, while community members may be

burning less, other people may still start fires, accidentally or on purpose. In Tumbang Nusa, the community noted that more than 50 daily visitors come for multiple reasons, including fishing. Monitors are needed to check for fires and remind outsiders not to light them, especially during dry seasons.

While canal blocking and backfilling are the most effective methods for sustainably rewetting peat, community awareness of the canal blocks and the status of rewetting is low. Despite the requirement to engage with the community before establishing new deep wells and canal blocks, and the BRG's statement that most construction is carried out in collaboration with community groups (BRG 2019, page 24), we found that most respondents had minimal or zero awareness of canal blocks. This could be due to the small sample size or the timing of interviews, but it is surprising that community awareness was so low. This suggests that community engagement is not sufficiently inclusive and there is still a mismatch between high-level plans for rewetting and the reality on the ground. In Tumbang Nusa, only one interviewee was involved in the construction of deep wells and canal blocks (through the MPA), which could indicate that information had not diffused through the rest of the community at the time of the interviews. Thus, there is a key opportunity for more local involvement to increase awareness of where the deep wells are, which of them function properly, and how to use them during a fire. It is important for the local community to be familiar with the locations of deep wells and canal blocks and contribute to planning and assessing their effects. For example, if local villagers were empowered to 'own' the canal blocks and benefit from them through fishing or transportation, they may be more motivated (than external parties) to monitor effectiveness and contribute to maintenance. A system whereby longer-term monitoring and maintenance of canal blocks was linked to regular village payments could meet the dual national goals of fire prevention and improved local livelihoods. This is a missed opportunity for shifting emphasis towards (government agency supported) bottom-up development of alternative livelihood options on rewet peatlands as opposed to focusing on top-down metrics of rewetting infrastructure installations.

Installation of deep wells has been the most recognised and positively regarded rewetting operation to date, but it needs to be acknowledged that the utility of deep wells is questionable. The process of extracting water from below the peat to prevent or suppress fire is problematic because it may promote further lowering of the water table in the peat. Yet villagers seem to be unaware of this tension. Similarly, the locations of deep wells are not widely known amongst the community, the locations do not seem to coincide with the spatial distribution of fire risk, and their serviceability when needed has been questioned. The locations of deep wells shown in Figure 4 suggest they have been chosen for ease of access for installation rather than long-term utility for village fire-fighting needs. This is also reflected in the interview responses, which indicate that the deep wells are not located where fires occur. Furthermore, it is challenging to move pumps between wells; also, pump maintenance and fuel are community responsibilities that may not prove reliable in an emergency.

Our findings of low awareness of rewetting strategies and potential effects align closely with those of Uda *et al.* (2020a) in their study of peatland governance in Jambi and Central Kalimantan. The work of Uda *et al.* (2020a) highlights lack of knowledge across multiple factors as a severe limitation on the prospects for successful peatland restoration. They categorise the knowledge gaps as 'technical' (zero burning methods for land cultivation; access to appropriate tools to extinguish fires; accurate knowledge of peat depths and water table levels), 'political' (unclear land titles; lack of information sharing between knowledge agencies) and 'cultural' (alternatives to traditional peatland management and land clearing) (Uda *et al.* 2020a). The gaps in knowledge about rewetting plans and implementation highlighted by our research fit into all of these categories. We found technical knowledge gaps around the placement and design of canal blocks, backfilling and deep wells as well as their use, maintenance and evaluation; political knowledge gaps related to (lack of) local community involvement in decision making across scales and agencies along with accountability for impacts; and cultural knowledge gaps with regard to livelihood options on rewet peat. In addition, the tensions between bottom-up needs for alternative livelihoods and top-down priorities for quick results are barriers to success.

Rewetting is complex because multiple objectives need to be balanced and these objectives can conflict and be contested. They include aims for economic and environmental outcomes, human and non-human priorities, infrastructure designs and implementation pathways (Uda *et al*. 2020a, Ward *et al*. 2020). Based on the responses of our sample of interviewees, the community felt they lacked engagement in decisions and planning processes and were not involved in the implementation of rewetting programmes. Even a highly resourced and flexible community will face

difficulties in responding to system change when they are excluded from the processes that will directly affect them (Bammer 2013, Fleming *et al*. 2021) and have no input in choosing the types of funding and training opportunities that may flow from these directives. Although participatory processes do not guarantee perfect outcomes (Gillespie 2012), they offer one way to reduce the possibility of devastating negative outcomes for local communities. Our work shows that there is still a large gap in community engagement in peatland rewetting, even in Tumbang Nusa, which is one of the most actively supported villages in this regard. It is important to recognise that the BRG process of restoration does involve the community, but it is likely that the scale of change required means the community involvement needs to be deeper and longer than is currently supportable by BRG. It is also clear that BRG engagement could be improved by focusing on rewetting and associated livelihood transformations to a greater degree.

New livelihood options that enable people to utilise rewet peatlands require urgent research and socialisation; plant species with economic value that thrive under wet conditions, and technologies that enable payments for maintenance of rewetting infrastructure are two examples. To be empowered, communities cannot be at the mercy of market price fluctuations or limitations on skills or infrastructure. Our interviewees noted that peatland areas were important for their livelihoods, but also that peatlands could not be relied upon as a stable source of income because of instability in the market prices of crops and commodities, lack of knowledge about how to work with wet peat, and resource limitations for new enterprises. Currently, some peat is being extracted/mined for sale and use in local nurseries. While peat extraction is unsustainable and conflicts with peatland conservation, the area of peatland affected by these operations is small (typically less than 100 m^2 per nursery business) relative to the areas being restored, the extracted peat will mostly be returned to the landscape when the cultivated saplings are planted out, and the species grown in nursery cultivation are typically being used in wider peatland restoration efforts. This highlights the need of villagers for livelihood options that are compatible with both rewetting and long-term sustainability, and many of the crops currently being promoted (e.g., sengon, pineapple, dragonfruit, watermelon) remain unsustainable options for the longer term because they require the water table to be at least 30–40 cm below the surface (Uda *et al*. 2020b). Although these crops provide income in the short and medium term, they can only be considered as a temporary option if full rewetting of the soil profile and a transition to peat swamp forest is to occur. Most species that are compatible with fully rewet peat, such as jelutung (*Dyera* spp.) and belangiran (*Shorea belangaran*), are suitable for providing longer-term income needs rather than short-term and medium-term needs (Uda *et al*. 2020b). Agroforestry systems are one option that allow a transition to full rewetting once the trees start to produce an income.

Empowering local communities requires political and cultural change, as well as local level change, to share costs and benefits more transparently and fairly (Ward *et al.* 2021). Collaboration across state and non-state actors, effort in monitoring and evaluation of rewetting activities with results made openly available, and strengthened coordination of governance and compliance are all needed (Januar *et al.* 2021). Sustainable livelihoods based on peatlands will require innovative combinations of traditional knowledge, revegetation, agroforestry (see Jaya *et al*. 2022), peatland uses such as fishing and harvesting of non-timber forest products, supply chain developments, and new approaches including payment schemes for maintenance of the rewetting infrastructure and ecotourism in niche areas.

In conclusion, our findings indicate that the community in Tumbang Nusa is committed to the need for zero burning and comfortable with the government's initiatives to encourage it. However, peatland rewetting in Tumbang Nusa is still a long way from being realised in terms of social awareness, acceptance and engagement. The key installed infrastructure comprises around 250 deep wells, and most of the community are peripherally aware of these but lack knowledge about their specific locations and how they will be used. Local people think that deep wells are useful for rewetting, but the premise that deep wells can be used for broad-scale rewetting is flawed because of the scale of rewetting required and because the surface soil around deep wells will dry out and still be susceptible to fire whenever active pumping is not in progress.

Our interviews revealed that there was surprisingly low understanding amongst the community of how the rewetting process would work, given that Tumbang Nusa has been a focus for rewetting engagements, and implications for the community's use of peat after rewetting had not really been considered. Canal blocking is a longer-term solution for rewetting but, so far, only a few canal blocks have been installed, with little effect on local people. If full rewetting were to take place, major changes for the community and their options for use of the peatland could be expected (Fleming *et al*. 2021). Our results show that community support

for restoration of drained peatland through rewetting is high, but the long-term viability of livelihoods on rewet peat is still uncertain, and communication around rewetting processes and implications, fire management and accountability is still limited. This means that responsibility (for limiting fires, responding quickly to outbreaks, and establishing new livelihoods) falls mainly on individual residents while outsiders, government and non-government organisations bear less accountability for initiatives that may not be well aligned with community goals or effective in restoring peatland for the longer term (Uda *et al*. 2020b, Fleming *et al*. 2021).

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AUTHOR CONTRIBUTIONS

AF and DM principally wrote the manuscript with contributions from all authors. BP and AH collected, transcribed and translated the data. AF conducted the analysis of interview data. DM and SG principally conducted the assessment of livelihoods, with input from all authors. All authors contributed local or specialist knowledge to the interpretation of results and approved the manuscript.

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Appendix: Extra quotes from interviews

"The deep peat area is located along the Trans-Kalimantan highway, about 9–12 metres deep, I do not know how big the area is." (Interview 6)

"What I know is that there is deep peat with an approximate depth of 3–4 metres located at the entrance of Trans-Kalimantan highway, especially on the border between Tumbang Nusa and Taruna. There is deep peat also located across from the village, across the Kahayan river, I don't know how deep it is." (Interview 7)

"I think Tumbang Nusa is divided into several areas: in Selat Nusa is shallow peat, across the highway is deep peat, and in the North is medium peat and in the village is deep peat, I don't know the size." (Interview 13)

"I do not know what to think about it, because the bore-wells are installed in locations where there is no fire." (Interview 4)

"In the fire prone areas there has not yet been any irrigation or canal blocking." (Interview 2)

"I know enough about peat rewetting. Yes, there was peatland rewetting especially in the area of the village entrance, but it was not optimal even though there are already 250 bore-wells scattered over several points, because many of the wells are not functioning, and we are also lack bore-well units that work optimally. But basically nowadays, if it does not rain for 7–10 days, we will do peat rewetting in the area, even if personally I think it is not optimal yet." (Interview 7)

"Utilisation of peatland depends on the seasons. Only a few people work with wet peat, because it is wet and sticky." (Interview 4)

"It is good to restore the peat function when it dries out, by installing bore-wells and by building canal blockades so the peat is not damaged and to prevent fire." (Interview 7)

"Good, if it is conducted regularly, not only once in a while and by waiting for the fire to start." (Interview 11)

"Peatland has also become a habitat for fish in the drainage canals." (Interview 4)

"The community is very wary and afraid of being arrested by the police because to open the land we usually burn it and use it to plant paddy rice. Nowadays, we can say that nobody is planting paddy anymore." (Interview 10)

"I don't know, because the community livelihoods are difficult, and the Covid-19 makes it even worse." (Interview 11)

"Especially now with the Corona pandemic, the community business is already difficult, and it will get ever harder if there is fire again." (Interview 13)

"There was a time when a community member was arrested and detained for deliberately burning peat to clear land for cattle." (Interview 14)

"Burned peat soil was used as spawning grounds for snakehead, papuyu and snapper fish. Now it's not possible anymore because there are regulations prohibiting the burning of forests and land." (Interview 15)

"The peat gets burned and it is hard to put it out, it will cause smoke pollution, and shortness of breath which is dangerous for toddlers and the elderly." (Interview 1)