Agroforests, swiddening and livelihoods between restored peat domes and river: effects of the 2015 fire ban in Central Kalimantan (Indonesia)

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HIGHLIGHTS

- Dayak Ngaju villagers have traditionally combined agroforest and swidden/fallow rotations on riverbanks and shallow peat.
- Rich ethnobotanical knowledge, local soil quality indicators and ceremonies reflect long-term presence in this landscape.
- The 2015 fire ban has effectively stopped local rice cultivation as technical alternatives are not attractive.
- The agroforests, with durian and rubber as marketed products, continue to support livelihoods, but are not sufficient.
- Temporary jobs on canal blocking for the peatland restoration agency have filled the gap, but are not expected to last.

SUMMARY

If 150 years of continued use counts as a sustainability indicator, the river-bank agroforests in the peat landscapes of Central Kalimantan suggest solutions for current challenges. The 2015 fire season in Indonesian peatlands triggered a fire ban and peatland restoration response, prioritizing canal blocking and rewetting. However, sustainable livelihood options remain elusive. We report local ecological knowledge of soils and vegetation applied in land use choices in swiddens and agroforests in five Dayak Ngaju villages in Jabiren Raya and Kahayan Hilir subdistrict (Pulang Pisau, C. Kalimantan, Indonesia) on the banks of the Kahayan river and discuss impacts of fire-ban policies. Plots accessible from the river with no or shallow peat were traditionally preferred for swiddening, with various indicator plants and soil characteristics underpinning the choices. Without swiddening farmers depend on off-farm jobs and agroforests for income. More policy attention for non-peat riparian-zone agroforestry as part of peat landscape livelihood systems is warranted.

Keywords: agroforestry, ethnobotany, fire ban, local knowledge, peatlands, soil indicators, swidden

Agroforêts, cultures sur brûlis et moyens d'existence entre tourbières bombées et rivière: effets de l'interdiction des feux de 2015 au Kalimantan Central (Indonésie)

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Si 150 années d'usage continu comptent comme un indicateur de durabilité, les ripisylves agroforestières dans les paysages de tourbières du Kalimantan central suggèrent des solutions pour les défis actuels. La saison d'incendies de 2015 dans les tourbières indonésiennes déclencha une réponse d'interdiction des feux et de restauration des tourbières, en priorisant le blocage des canaux et le remouillage. Cependant, les possibilités de revenus durables demeurent plutôt insaisissables. Nous rapportons la connaissance écologique locale des sols et de la végétation appliquée aux choix d'utilisation de la terre dans les cultures itinérantes sur brûlis et les agroforêts dans cinq villages Dayak Ngaju dans les sous-districts de Jabiren Raya et Kahayan Hilir (Pulang Pisau, C. Kalimantan, Indonésie) sur les rives de la rivière Kahayan, et nous discutons les impacts des politiques d'interdiction des feux. Les parcelles accessibles de la rivière avec peu, ou pas de tourbe, ont été traditionnellement préférés pour la culture sur brûlis, avec diverses plantes-indicateurs et caractéristiques du sol guidant les choix. Sans culture sur brûlis, les exploitants dépendent d'emplois hors ferme ou de l'agroforesterie pour leurs revenus. Il est nécessaire de porter plus d'attention dans les politiques sur l'agroforesterie de bord de rivière sans tourbe comme faisant partie des systèmes de revenus des paysages de tourbières.

Agroforestería, roza y quema, y medios de vida entre los domos de turba restauradas y el río: efectos de la prohibición de quemas de 2015 en Kalimantan Central (Indonesia)

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Si el uso continuo durante 150 años cuenta como un indicador de sostenibilidad, la agroforestería en las riberas de los humedales (zonas de turberas, pantanos naturales) de Kalimantan Central, nos ofrecen soluciones para los desafíos actuales. La temporada de incendios en 2015 en las zonas de turberas de Indonesia desencadenó la prohibición de quemas y la restauración de turberas, dando prioridad al bloqueo de canales y a rehumedecer las turberas. Sin embargo, opciones sostenibles de sustento siguen siendo difíciles de alcanzar. Este estudio reporta conocimiento ecológico de comunidades locales sobre suelos y vegetación aplicado en decisiones sobre uso del suelo en áreas de roza, tumba y quema y sistemas agroforestales. Cinco poblados Dayak Ngaju en el sub-distritos de Jabiren Raya o Kahayan Hilir (Pulang Pisau, Kalimantan Central, Indonesia) fueron analizados en las orillas del río Kahayan y se discuten impactos de las políticas de prohibición de las quemas. Parcelas accesibles desde el río son preferidas tradicionalmente con o sin turbas poco profundas para llevar a cabo la agricultura de roza, tumba y quema, empleando varias plantas como indicadores, así como características fisicoquímicas del suelo para elegir estas opciones de manejo. Sin la posibilidad de efectuar roza, tumba y quema, los ingresos de los agricultores dependen de la agroforestería y de trabajos no agrícolas. Se justifica entonces que se preste más atención a las políticas destinadas a promover la agroforestería en zonas ribereñas sin turberas como parte del sustento en los ecosistemas de turbera.

INTRODUCTION

As elsewhere in Southeast Asia, livelihoods strategies and land use systems at the forest/agriculture interface in Kalimantan have gradually increased in intensity due to the interactions with global markets, followed by a 'dual economy' track at local scale of providing for local needs as well as income (Dove 2011). In a subsequent national-scale interpretation of a dual economy, logging concessions became a source of income primarily for stakeholders outside the landscape, while getting into conflict with local swiddening traditions as basis of local needs. Swiddening has for millennia of human existence been the basis for local food security strategies, through both its cropping and fallow phases (Cramb *et al*. 2009, Mizuno *et al*. 2013). In response to market demand for 'forest products', the fallows in many parts of southeast Asia transformed into agroforests that complemented remaining old-growth forests as a source of marketable products and local food (de Foresta *et al*. 2000, van Noordwijk *et al*. 2008a). Depending on accessibility and the terms of trade, transitions occurred to 'outsourcing' rice as a staple food that can be obtained from trading canoes as well as from swiddens, while other parts of the diet and the fuel needed to cook it remained locally sourced (van Noordwijk *et al*. 2014*a*). A switch from periodically shifting villages to permanent settlements with access to health and education services as well as government control, coincided with a greater role of the agroforests around settlements as provider of income though products such as rubber or durian. When land away from the river became claimed as 'state forest' (Galudra *et al*. 2011), the river-based economy became enriched with sawmills fed from commercial logging concessions, supporting the dual economy.

Changes in agricultural patterns from swidden to permanent cultivation occurred in many regions in Indonesia at various points in time (van Noordwijk *et al*. 2008a,b, Hariyadi and Ticktin 2012, Li *et al*. 2014, Dressler *et al*. 2017). A review of the declining role of swiddening in Southeast Asia (Fox *et al*. 2009) identified seven contributing factors, including the division of landscapes into forest and permanent agriculture, treatment of swiddeners as ethnic minorities within nation-states, privatization and commoditization of land and land-based production, and expansion of market infrastructure and the promotion of industrial agriculture. In a global assessment van Vliet *et al*. (2012) concluded that despite decline, swidden cultivation remains an important element of tropical forest-agriculture frontiers. In the context of climate change policies, van Noordwijk *et al*. (2015) distinguished between contexts where A) swiddening is still the locally preferred land use, B) contexts where there has been a voluntary shift to other sources of local and/or off-farm livelihoods, and C) contexts where policies, such as no-burn policies, are actively enforced and farmers urgently need alternatives. The use of fire for land clearing in landscapes with tropical peats is now in that third category and livelihood transitions are imposed on local communities. The challenge for public policies is to turn a type-C imposed abandonment of fire as traditional tool for re-opening swiddens into a type-B voluntary choice as there are attractive alternatives. Our case study delved into these issues.

Several of the large rivers of Borneo and Sumatra have an extensive lowland section where peat domes developed in the interfluvial areas. These peat areas did not support human settlement, but their low-intensity use complemented the river-bank agriculture and fishing. Only in the 1990's when more favourable areas had been logged and in part converted to plantations (either fast-growing trees under forestry rules or oil palm as an agricultural crop), attention shifted to these peatlands, where a lack of local claims meant less conflicts than on mineral soils. Conversion of large areas of Indonesian peatland into agricultural lands for estate crop production and plantation forest brought short-term economic gains, but also posed major environmental, health and economic risks and loss of globally significant biodiversity contained in natural peat swamp forests (Uda *et al*. 2017). Peat-based communities in Central Kalimantan had to adapt their livelihoods to changing peatland conditions and management policies (Jewitt *et al* 2014). The most striking case is the Mega Rice Project, which logged and transformed a million hectares for resettling farmers from elsewhere to grow irrigated rice. Currently known as the Ex Mega Rice Project

(EMRP), technical and social failure of the resettlement scheme has shifted attention back to the original inhabitants of the peatland landscape and to efforts to restore ecosystem services (provisioning, regulating, cultural; Law *et al*. 2015*a*).

Under President Joko Widodo's first administration period, the government prioritized restoration and rehabilitation of peatlands by establishing the Peat Restoration Agency (BRG), based on Government Regulation No.1 of 2016, to accelerate the recovery of integrated functions of peat hydrology and avoid future fire episodes like the one experienced in 2015. One of the priorities of BRG activities in Central Kalimantan Province is in Pulang Pisau District, in the form of canal blocking to reduce the rate of drainage and keep the peat dome wetter at the start of a dry period and making bore holes (wells) to have water readily available to extinguish fire if needed. The aim of these activities is to restore a shallow ground water level and reduce the fire risk in remaining forests and agricultural land. Both state-sponsored efforts that tried to undo the failed projects together with locally fire ban for agricultural purposes have created new challenges for existing swidden practices.

Previously, internationally funded efforts to control carbon emissions from the landscape had revealed that the area is a 'hot spot' for contested claims and conflicts between forest authorities and local communities over the forest designation of riparian-zone lands that had previously been respected as under 'adat' (customary law) control (Galudra *et al*. 2011). Project documents and planned interventions did not refer to agroforests as part of the traditional land use or conceive them as part of a desirable solution.

The absence of 'agroforest' categories in the legal frameworks for land use planning and the lack of interest in the production plus conservation properties of these systems (Fay & Michon 2005, Fay & Sirait 2005, Michon *et al*. 2007), has led to a conceptual dichotomy between agriculture and forestry that has discouraged gradual transitions and intermediary systems. De Foresta *et al*. (2000) described agroforests in Indonesia as based on planting beneficial trees on farm (often starting with swiddens), with tree canopy structures that resemble tree structures in forests, providing a home to many forest organisms. Van Noordwijk *et al*. (2019) discussed how interpretations of agroforestry as a dynamic system of natural resource management, through integration of various types of trees species on land and in agricultural landscapes, requires policy change to secure the economic, social and environmental benefits it can provide to various segments of society. These benefits can be understood as four type of ecosystem services i.e. (a) provisioning of foods, timber, fibre, fruit and medicines, (b) regulating the flow of clean water and clean air (Mainka at al. 2008), (c) supporting the development of biodiversity, soil formation, and (d) preserving culture, landscapes beauty, and maintaining germplasm (MEA 1994).

Recent land-use choices follow profitability at the expense of ecological functions in Indonesian smallholder landscapes (Clough *et al*. 2016), as the more profitable oil palm and rubber monocultures replace forests and agroforests critical for maintaining above- and below-ground ecological functions and the diversity of most taxa. According to their analysis, strategies to achieve an ecological-economic balance and a sustainable management of tropical smallholder landscapes must be prioritized to avoid further environmental degradation. Such strategies will have to start from a stocktaking of what exists.

Analysis of land use plans for the area surrounding the EMRP (Law *et al*. 2015*a*, 2015*b*) have considered 'smallholder agriculture' and 'riparian forest' but not the 'riparian agroforest' that can be seen in the Jabiren Raya sub district along the Banjarmasin – Palanga Raya road. Government documents attributed the fires to 'slash-and-burn' practices by local communities(also known as swidden re-opening) and to land clearing to support land claims (Medrilzam *et al*. 2014). Unintentional spread of such fire use, without effective control, was seen as part of the cause in the fires culminating in the 2015 event (Ardhian *et al*. 2016, Lohberger *et al*. 2018). In response, the fire ban that previously had exempted small-scale farmers was reframed to apply landscape-wide to all actors (Page and Hooijer 2016). Where prior to the 2015 fires a lack of commitment to act had been the bottleneck (van Noordwijk *et al*. 2014b), the agenda shifted to finding practical, operational solutions after the Peatland Restoration Agency (BRG) had been constituted. Together with the canal blocking and rewetting that tried to undo the failed projects of the 1990's, the fire ban created new challenges for existing swidden practices. Economically attractive forms of 'paludiculture' and agroforestry not requiring extensive drainage (ASEAN Secretariat 2013, Wetlands 2016, Widayati *et al*. 2016, Medrilzam *et al*. 2017) are urgently needed in these landscapes, both for the riparian edges and the peat domes. Paludiculture is a productive use of peat swamp to protect peatlands without drainage or canal blocking so that the peat stays wet. Paludiculture (Tata 2019) can provide fruits such as durian (*Durio* sp.) or mango (*Mangifera* sp.), commercial wood species like kahui (*Shorea blangeran*), and medicinal plants such as papar buhu (*Antidesma coriaceum* Tul). Existing agroforests close to the river and their historical interaction with swiddens may offer traditional knowledge of soil and water management (Barrios *et al*. 2012) that is relevant in the current discussions. Ethnobotanical surveys may reveal which plants are considered to have local indicator value of environmental conditions, beyond any direct use value.

The current exploration of local knowledge and practices in the area between the Kahayan river and the peat domes to its West and East was initiated to answer the following questions:

1. How are land use practices including swiddening and agroforests positioned in the river-peat dome gradient and associated with local knowledge of soil and water management?
2. How is land use associated with ethnobotanical knowledge of plants as indicators of land quality and as sources of livelihoods?
3. In what way did the 'fire ban' of 2015 affect existing land use practices and food production by the local communities and what alternative options do they currently have?

FIGURE 1 *Google.Earth image of the landscape in Pulang Pisau regency southeast of the provincial capital Palangka Raya along the road to Banjarmasin, with the riparian agroforest in Jabiren along the Kahayan river, intact peat swamp forest to the West (left) and areas affected by the Ex-Mega-Rice project to the East*



METHODS

Geographical context

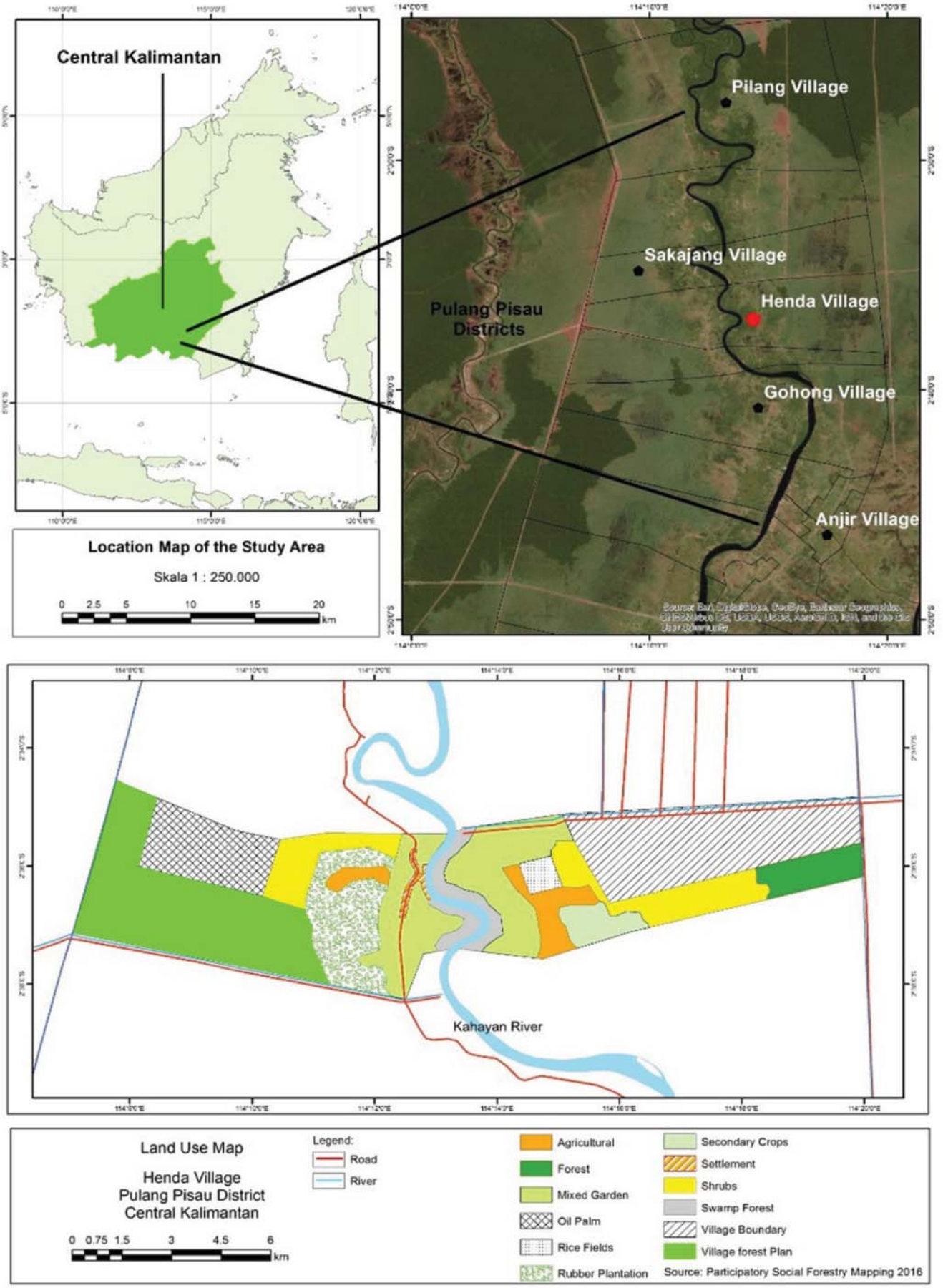
Central Kalimantan is dominated by river deltas and wetlands that are now understood to be part of Peat Hydrology Units (KHG = Kesatuan Hidrologi Gambut). A large area of wetlands (around 440,000 ha) is located in the Pulang Pisau Regency. It became known as 'Block C' in the EMRP (Lestari 2016). The economic wheel in Pulang Pisau Regency depends on the agricultural sector (Pemerintah Kabupaten Pulang Pisau 2015), while the availability of agricultural land area is still limited; therefore, the potential for conversion of forest land remains a key interest. Five villages on the Kahayan river were selected for this study, three (Pilang, Henda, Sakakajang) in Jabiren Raya Sub-District (Pulang Pisau District), two (Gohong and Anjir Pulang Pisau) in the Kahayan Hilir Sub-District (Figure 2).

The study area (1°32′00′-3°28′00 South, 113°30′00-120°00′00 East) borders Gunung Mas Regency in the North, Kapuas Regency in the East, the Java Sea in the South and Katingan Regency and Palangka Raya City in the West. The five study villages are: area of Pilang (area about 180 km^2, 1320 inhabitants, 7.3 km^{-2}), Sakakajang (60 km^2, 768 inhabitants, 12.8 km^{-2}), Henda (538 km^2, 648 inhabitants, 1.2 km^{-2}), Gohong (60 km^2, 1808 inhabitants, 30.1 km^{-2}), Anjir Pulang Pisau (22 km^2, 4407 inhabitants, 200.3 km^{-2}) (BPS 2018*a*, 2018*b*). Henda Village, the oldest among the five, with the most extensive land area and widest range of land uses, in the middle of the study landscape was chosen for more detailed observations.

Collection and analysis of data

The local communities along the Kahayan river identify themselves as Dayak Ngaju. Various groups of migrants, under the government-sponsored transmigration program as well as spontaneous migrants, have also settled in the area, coming from Bali, Java, Flores and elsewhere in Kalimantan. Only villages that described themselves as of Dayak Ngaju ethnic origin were considered in this research, as we wanted to document local ecological knowledge with historical roots in this landscape. Permission for research was obtained from the village elders, and the first author, with five years' experience in the area was welcomed in the homes of many villagers, with follow-up interviews in the field, and participation in village events. Data collection was carried out by surveys, field observations, and in-depth interviews with 20 key informants (purposive sampling) consisting of 18 men and 2 women.

FIGURE 2 *(A) Five study sites in Pulang Pisau District, South Kalimantan, (B) Land use types in the peat landscape (BRG 2018)*



Key informants were land-owners with deep knowledge of the land history from forest-land clearing stage to land cultivation, had knowledge about various types of beneficial plants and/or have been managing land in these villages. Further knowledge was shared by women who joined in the collection of biophysical data. In-depth interviews were conducted in the Dayak Ngaju language and Bahasa Indonesia. The interviews were recorded, fully transcribed and interpreted into Bahasa Indonesia. Where interviews appeared to provide conflicting information, joint field visits were made to ensure information was correctly interpreted and was related to field data. Data on shallow-peat tree indicators and useful ethnobotanical plants were then matched with the tree flora for Kalimantan edited by Whitmore *et al*. (1990).

A quick soil assessment was carried out using Munsell Soil Color (1994) charts. In-depth interviews and joint field visits explored local ecological knowledge of indigenous farmers. Some of the information gathered was related to soil quality, an indicator of vegetation on peatlands. Problems faced by farmers related to the implementation of government policies in preventing fires were a common topic of discussion, as well as the impact of socio-economic changes on community cultivation on peatlands. All data obtained were described in a qualitative descriptive manner (Miles *et al*. 2014, Robertson *et al*. 2017, Schüler and Noack 2019), and are presented in an anonymized way and in summary form in this paper to respect the privacy of respondents.

RESULTS

Land use patterns

Part of the current agroforestry lands managed by Dayak Ngaju farmers were passed down from three or four generations before the current owner. Allocation and management of those lands, as well as the use of communal land rights and land conflict resolution always refer to the customary leader called Mantir Adat, who is elected by villagers within the customary community. Agricultural activities in the Dayak Ngaju culture are described through four important stages, namely land selection, carrying out traditional ceremonies, planting and harvesting (Table 1). Traditional ceremonies contain ritual elements in social life which are believed to provide success and safety for farmers.

TABLE 1 *Land use calendar for swidden cultivation and the swidden-fallow cycle*

Implementation	Stages	Activity
Before clearing the forest for cultivation	Ritual (salvation) Ceremony (*mangariau, menyanggar*)	Ceremony of salvation and success by securing agreement from supernatural beings in the prospective land. Activities led by adat leaders or shamans, by washing offerings in the Kahayan river, in containers made of bamboo (*kelangkang*). The upright position of the *kelangkang* when it is washed away, signifies nature allows the land to be cleared. All customary rule violations, will attract a curse (*pahuni*).
July	Open land	Conducted in groups and led by someone considered an elder
July–August	Land clearing	Cutting down small trees and herbs (*mandirik*) and cutting down large trees (*maneweng*).
September	1. Burning the cut biomass (*manusul*)	Slash and burn activity after making firebreaks (around the plot) and keeping fire from creeping or jumping to other areas (*pusuk menyawung*), guarded in groups by working together (*handep*).
September	Planting rice (*manugal*)	Planting upland rice varieties (mountain rice, '*iwau*', '*geragai*', '*kawung*' and red rice). Rice seeds are obtained from the old generation, bought or borrowed (*manalisih*) from farmers who still have them. After 10 days, rice will be replanted (*maneseng*) to replace dead rice plants. This activity is in conjunction with growing vegetables (*mimbul sayur*), to fulfil daily needs; types of vegetables planted include beans, *karwila* (*Luffa acutangula*), hot pepper (*Capsicum frutescens*), cucumber (*Cucumis sativus*), bitter gourd (*Momordica charantia*) and eggplant (*Solanum melongena*).
November–December	Weeding (*membawau*)	Weeding is carried out when the rice is 2 months old, to avoid damage on main crops.
March	Harvesting rice (*menggetem*)	
Subsequent years	Subsequent rice crops, or transition into agroforest	Repeated rice planting activities for up to 3 or 4 times depend on soil fertility. If soil fertility decreases, shown by a decline in rice production, then land management shifts to (inter)planting (*sisipan*) rubber and local fruits such as various mangoes (*Mangifera* sp.), cempedak (*Artocarpus integer*), durian (*Durio* sp), manggosteen (*Garcinia mangostan*), rambutan (*Nephelium lappaceum*) and 'rambai' or 'buah menteng' (*Baccaurea motleyana*).

Local knowledge of 'improved fertility' by the traditional and controlled use of fire in land clearing, locally termed '*manusul*', is supported by soil science. Ash produced from wood and litter burning during this manusul provides soil nutrients and increases soil pH (Rodenburg *et al*. 2003, Huotari *et al*. 2015), as it has high concentration of K, Ca and Mg (Hairiah *et al*. 2011), while organic P can be mobilized (Ketterings *et al*. 2002). Rice can be planted for 3–4 years only and is followed by planting of rubber and fruit trees, after which land is left as 'fallow' for several years until a multistrata agroforestry is formed (Figure 3A).

Utilization of land for agriculture in Henda historically started from the Kahayan riverbank (both on the right and left side of the river). More recent agricultural land uses continued to develop at increasing peat depths and distances to the river (Figure 3B).

Local knowledge of soil fertility

Peat swamp land use for agriculture along the banks of the Kahayan river needs to take the tidal pattern of the river into account, some 50 km from the sea, as access by canoe is best during high tide. An important aspect of local knowledge used by Ngaju Dayak farmers and passed on from generation to generation relates to site selection, land suitability and vegetation that indicates land suitability for farming. Indicators used for land selection for farming are summarized in Table 2.

The location for farming in the study area is along the Kahayan riverbank and close to the settlements. The type of land management on peaty land is selected based on the level of water saturation, soil acidity, and nutrient availability for plants. This land is not entirely flat; there are parts in the form of higher basins and surfaces. Farmers prefer higher land surface with peat thickness less than 20 cm (which is also just a mineral soil), which is suitable for annual crops such as upland rice and vegetables. Farmers will plant trees (rubber and various local fruits) in the third or fourth year of cropping and leave it to become an agroforest. The land is called *high land/hanging plot/embankment land* or meaning high land/transition lands/embankment land, characterized by being located near the river and unflooded even at the peak of the rainy season or at the highest tides. On the other hand, there are also land conditions that are avoided by farmers, namely *petak rendah, hapu, luwau*. These lands are positioned in low-lying land so that they can be flooded during the rainy season and the highest tides. Peat thickness in such lands was observed to be 20 to 50 cm.

There are various terms in local use for the maturity of peat, such as "raw" peat, "half mature" or "half-cooked", and "mature" or "cooked" peat. "Raw" peat is found in all peatlands that have never been managed or cultivated before. Farmers choose peatlands for farming mostly based on peat depth, preferring shallow (thicknesses <20cm) or medium (thickness 20 to 50cm) peatlands. The half-mature peat does not exist on peatland with a thickness of <20cm but is still sometimes found on peat land with a thickness of 20–50cm.

The mature peat commonly called as "*petak asli, petak murni*" or "original" or "pure" plot implies that the land has no (or no more) peat; what remains is a clay or loamy soil, with lumpy soil structure. The colour of the mature peat soil

FIGURE 3 *(A) Four stages of activities in the formation of agroforests with forest-like structures, (B) Development of various land uses at various distances to the Kahayan river and at various peat depths in the village of Henda*

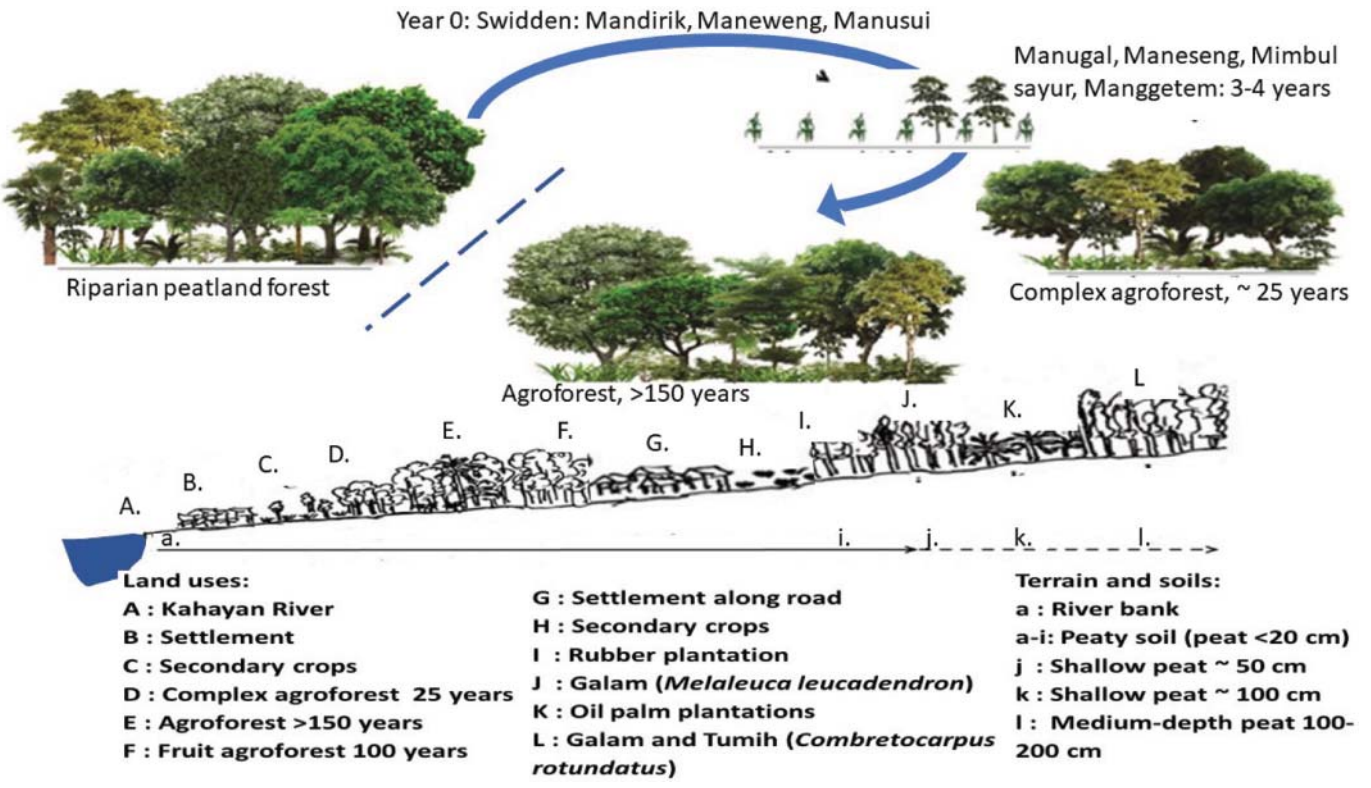


TABLE 2 *Indicators used in selecting plots for swiddening*

No	Desired condition	Unwanted condition
1.	Agricultural land along the riverbank. The selected land is within 2 km from the river (which aligns with historical land rights).	A distance to the river of more than 3 km.
2.	* Peat thickness <20cm, "the length of a hoe, knife blade, or ankle". * High-lying plots on or close to embankments (also "hanging plots") because at the peak of the rainy season or at high tides they will not be flooded. * The soil is called "*petak bervitamin, petak dingin, tanah protein"* meaning plot has a lot of vitamin, soil is cool and has a lot of protein	• Peat thickness in the range of 20–50cm. • Low-lying land, "petak rendah, hapu, luwau", because it is flooded in the rainy season or during the highest tide. • Plots where plant growth is not optimal, so called "*petak kerdil, petak kurang protein, petak panas"* meaning plot that has dwarfed plants, poor nutrient supply and is prone to droughts.
3	Soil that can form lumps "*bagumpal*" when squeezed, indicating it contains clay, and may have a good structure	The soil is lumpy, but easily collapses when squeezed and is likely unable to store water.
4	Presence of positive indicator plants (see Table 3)	Presence of negative indicator plants (see Table 3)

is dark brown (7.5 YR 3/2 dark brown), yellowish (10 YR 4/4 or dark yellowish brown) or greyish (10 YR 4/2 dark greyish brown); the condition of the mature peat is shown in Figure 4.

Half-mature peat sometimes can still be found in peat land that has a thickness of 20–50cm (shown in figure 4d and 4e), the colour is black "*babilem*" (5 YR 2.5 / 1 black), with a crumbly structure; it is unable to store water and dries quickly. The process of changing half-mature peat into mature peat requires a very long time, because it must go through the process of repeated combustion and drying of the land. The land is commonly used for planting rubber, fruit trees and oil palms. Burning plant biomass is a major part of peatland farming. It produces ash "*kawu baputi*"; farmers call the ashes as "*pupuk kompos ladang*" or "field compost". As shown in Figure (4f) ash from burning land in 1994 was still recognizable. Field observation in the mature-peat, half-mature, and *pupuk kompos ladang* is shown in Figure 4.

The main transportation in the peat landscape is based on *Jukung*, a traditional boat used to bring agricultural product from the garden to the market (Figure 4g). The "handel" canal is a transportation route that also has a function to dry up the inundated land. Canals are dug and maintained by groups of farmers (*baring hurung*).

Ethnobotanical knowledge of plants

Farmers recognize various indicator crops for cultivation in the local context, as shown in Table 3 and Figure 5. Seven types of indicator plants for "*tanah tinggi /petak gantung/ tanah pematang*" were commonly used, while the condition of "rendah, hapu" or "luwau" plots or peat swamp is indicated primarily by the presence of a type of fern (*Stenochlaena palustris*), grass (*Leersia hexandra*) or a specific tree (*Melaleuca leucadendron)*. Some of these indications may not be valid outside of the local context.

Agroforestry in Pulang Pisau district is generally rubber-based, with local fruits as additional sources of income. The oldest agroforest is still actively maintained and is more than 150 years old. The land was the site of former homesteads and homegardens that transformed into an agroforest. The next generation benefitted and sought to preserve local species such as binjai (*Mangifera caesia*), dehuyan (*Durio zibethinus*), paken (*Durio kutejensis*), kasturi (*Mangifera casturi*) and non-cultivated, volunteer plants such as sungkai (*Peronema canescens*), mahang (*Macaranga* sp.), Kahui (*Shorea balangeran*).

Table 4 provides information about local plants found in agroforest, which are both cultivated and spontaneously established (rather than planted). Most of them come from *Anacardiaceae* (22.7%) and *Moraceae* (13.6%) families, where the rest come from other 20 botanical families. The life forms of those plants are mostly in trees (93.9%), and others are ferns (3%) and herbs (3%). Local people use those plants as source of food, fruits, side dishes, medicines and building materials. They still are important in local livelihoods, especially because natural forest is not accessible.

Economic Status of Local Agroforestry

Rubber and fruit-based agroforestry is the most important source of income for local farmers. Rubber prices (at the farmgate) have fluctuated over the past decades, with a high price level at Rp. 17,000/kg in 2010 to Rp. 8,000/kg in 2018. Farmers can get around 15 kg of rubber/tapping day, coming from around 300 trees (approximately 1 ha at common stand densities). Income from rubber sales (at 2018 prices) was around Rp. 360,000/week for three tapping days. However, rubber farmers' income from agroforestry will decrease during the rainy season, when trees are tapped only once a week. As rubber prices plummeted, farmers became interested in trying new options, which are promoted by the local government, namely planting sengon (*Paraserianthes falcataria)* for local pulp and paper mills. With an expected price of Rp. 400,000/m^3, sengon grown in monoculture tends to replace rubber trees. However, not all farmers participated in such programs because they have to provide the land for it and

FIGURE 4 *Indicators of soil quality: a), b) and c) Fertile soil, "with vitamin", "protein", "cool", indicating "well-cooked" or mature peat, d) and e) "half-cooked" peat soil, f) ash, g) preferred position relative to canal ("handel") for easy access*



FIGURE 5 *Plants used as soil fertility indicators: (a) Simpur (*Dillenia sp*), (b) Mahang (*Macaranga *sp.), (c) Lepu (*Korthalsia flagellaris*), (d) Suli (*Hedychium coronarium*)*



capital for land preparation. Hence, only some joined the program. To date, no data on sengon production is available, because it was just planted three years ago, and could, supposedly, be harvested at the age of five years.

Many farmers felt they could not make ends meet, arguing that farmers needed an estimated monthly rice consumption of 30 kg for a family consisting of two adults. The income of farmers from fruit tree production is influenced by the year and fruiting season. This is not worth the expenditure for rice, whose prices vary between Rp. 7,000 kg to Rp. 14,000 per kg in 2017 and 2018 (Disperindakop UKM, 2018). In the harvest season, some types of fruit are sold to traders who come to the garden, but durian species will be prioritized to be distributed in large families by a father who determines the management

TABLE 3 *Various plants species as indicators of shallow or deeper peatlands*

Local name	Botanical name	Family	Life form	Type of Land
Lepu, dahanen	*Korthalsia flagellaris*	Arecaceae	Palm	Shallow peatland (peat thickness <20 cm) in land described as *"pematang, tanah tinggi, petak gantung"*
Simpur	*Dillenia sp.*	Dilleniaceae	Tree	
Mahang	*Macaranga trilobal*	Euphorbiaceae	Tree	
Tapanggang	*Adenanthera pavonina*	Fabaceae	Tree	
Hampuak	*Baccaurea bracteata*	Phyllanthaceae	Tree	
Papar buhu	*Antidesma coriaceum*	Phyllanthaceae	Tree	
Suli	*Hedychium coronarium*	Zingiberaceae	Herb	
Kalakai	*Stenochlaena palustris*	Blechnaceae	Fern	Inundated land, peat thickness 20 to 50cm in "*petak rendah, hapu, luwau*"
Gerigit	*Leersia hexandra*	Poaceae	Grass	
Galam	*Melaleuca leucadendron*	Myrtaceae	Tree	

of the garden (inheritance) and selling the fruit. Durian is a favourite fruit that has a high selling price compared to other fruit yields so harvesting durian fruit will be a priority.

The average durian weight is 3 kg at the price of Rp. 30,000 per piece. Some fruits can reach a weight of 7 kg, which is worth Rp. 70,000 per piece. Each durian tree can produce 100–500 fruits. One farmer stated his experience that durian trees will bear more fruit if they reach 100 years of age, which can produce 600 durians/tree. This is the main reason for maintaining the durian tree for the next generation.

Durian harvest is a customary event to be maintained alongside cultivation activities by the Dayak Ngaju tribe. When taking turns caring for and waiting for the durian harvest, families will gather from various villages once a year to remember their heritage and genealogy. They realize that the durian crop, which has a high sale value, must be managed to avoid conflict in the family. Joint harvests are carried out in turn according to schedule and agreement, and the harvest yield of each family depends on the amount of durian that falls to the ground because it has ripened.

In addition to the harvested fruit, farmers also get benefit during the season of durian flowering. Farmers repel insect pests by burning litter piles obtained from cleaning the soil around the durian tree. At this time, farmers often catch bats that pollinate the durian flowers using nets to be then consumed as a traditional family dish (NB this observation was before the global SARS-COV2 pandemic attributed to bat consumption).

Effects of the 2015 fire ban

In an effort to prevent forest fires, a fire ban was issued by the Governor of Central Kalimantan in Regulation No. 49 of 2015. The ban impacts farmers in the study area, who are prevented from opening land for swiddens in their traditional way because there are legal sanctions. Farmers are accustomed to slash-and-burn land clearing techniques in farming (relying on a swidden-fallow rotation), with strict controls on escaping fire and local sanctions if accidents happen.

Previously farmers never bought rice but instead sold it for additional income. Now, farmers reported that they had to become rice buyers, instead of being rice sellers. This meant a lot to them, as in the prevailing norms it is only farmers who do not work that do not have rice for their family consumption with some surplus to sell.

Farmers generally acquire agroforests from previous generations, so farmers can still get income other than farming swiddens. However, since the living standards and associated expenditure are increasing, the yield from agroforestry is no longer sufficient. Farmers' land which was previously used for cultivation, has been sold at high prices to adjacent oil palm plantations East of the river. Those (ex)farmers are now looking for off-farm jobs, including temporary jobs under BRG programs (canal blocking and rewetting), gold mining, fishing, and sometimes as labourers on oil palm plantations. However, they still work in, and take care of the agroforests.

A government program has been introduced for "Rice Fields Development" (Program Cetak Sawah Baru), emphasizing cultivation without burning. The farmers are equipped with tractors, seeds and fertilizers. However, when land clearing is done by heavy equipment instead of fire, it leaves woody stems and roots on the soil surface (which used to be burnt). The use of tractors is also still considered to be too expensive for farmers, while for many their swiddens are across the river from where the village is located, so that many farmers decided not to cultivate their land anymore. Also, rice seeds that are given to farmers are not local seeds that are commonly planted by farmers. Based on these reasons, local farmers considered the government program not to be suitable.

The culture of growing rice (*manugal*) in mutual cooperation (*handep hapakat*) is related to rituals as part of the social life of the Ngaju Dayak tribe. However, manugal culture cannot be carried out anymore because slash and burn activities have been banned. Farmers expect that there are solutions and guidance on sustainable land management without burning, because the old method of slash and burn management that has been carried out from generation to generation, is considered practical and inexpensive and is related to culture. Changes to agricultural habits that have been applied for many generations are not easy to implement. Furthermore, farmers wish the government to examine the ban and allow

TABLE 4 *Useful plants (arranged by botanical plant family) in (agro)forests, according to local informants*

Local Name	Botanical name	Family	Plant type	Use	Actively managed?
Barania	*Bouea macrophilla*	Anacardiaceae	Tree	Fruits, side dishes	Yes
Binjai	*Mangifera caesia*	Anacardiaceae	Tree	Fruits, side dishes	Yes
Hampalam[*]	*Mangifera sp.*	Anacardiaceae	Tree	Fruits, side dishes	Yes
Kasturi	*Mangifera casturi*	Anacardiaceae	Tree	Fruits, Building materials	Yes
Tarantang	*Campnosperma coriaceum*	Anacardiaceae	Tree	Medicine for uric acid (bark), building materials	No
Jelutung	*Dyera costulata*	Apocynaceae	Tree	Latex, Building materials	Yes
Kalakai	*Stenochlaena palustris*	Blechnaceae	Fern	Food supply after giving birth	No
Jinjit	*Calophyllum hosei*	Calophyllaceae	Tree	Building materials, menstrual medicine	No
Manggis	*Garcinia mangostana*	Clusiaceae	Tree	Fruit medicine for skin disease (latex)	Yes
Simpur	*Dillenia sp*	Dilleniaceae	Tree	Medication for dysentery (young shoots)	No
Sungkai	*Peronema canescens*	Verbenaceae	Tree	Building material	No
Kahui	*Shorea balangeran*	Dipterocarpaceae	Tree	Furniture	No
Tamang	*Elaeocarpus glaber*	Elaeocarpaceae	Tree	Food ingredients (fruit)	No
Karet[#]	*Hevea brasiliensis*	Euphorbiaceae	Tree	Latex, Building material	Yes
Mahang	*Macaranga trilobal*	Euphorbiaceae	Tree	Building material	No
Petai	*Parkia speciosa*	Fabaceae	Tree	Vegetable	Yes
Tapanggang	*Adenanthera pavonina*	Fabaceae	Tree	Black colouring (rattan woven)	No
Rambai	*Baccaurea motleyana*	Hyllanthaceae	Tree	Fruits, vegetable (rind)	Yes
Tabulus (kalangkala)	*Litsea angulate*	Lauraceae	Tree	Ingredients	No
Putat	*Barringtonia asiatica*	Lecythidaceae	Tree	Ingredients (vegetables)	No
Dehuyan	*Durio zibethinus*	Malvaceae	Tree	Fruits, side dishes (*tempuyak*), timber, the root used as a medicine after childbirth	Yes
Paken	*Durio kutejensis*	Malvaceae	Tree	Fruit	Yes
Kambasulan	*Pternandra galeata*	Melastomataceae	Tree	Skin medicine	No
Ruku	*Lansium domesticum*	Meliaceae	Tree	Fruit, side dishes, vegetable (rind)	Yes
Cempedak	*Artocarpus integer*	Moraceae	Tree	Fruit, side dishes, vegetable	Yes
Nangka	*Artocarpus heterophyllus*	Moraceae	Tree	Fruit, vegetable	Yes
Talayar	*Ficus septica*	Moraceae	Tree	Fodder, hemorrhoids medicine	No
Hampuak	*Baccaurea bracteate*	Phyllanthaceae	Tree	Building material, shoots (as vegetable)	No
Papar buhu	*Antidesma coriace*	Phyllanthaceae	Tree	Medication for delivery (root)	No
Mangkudu	*Morinda citrifolia*	Rubiaceae	Tree	Medication for kidney stones, high blood pressure	No
Rambutan	*Nephelium lappaceum*	Sapindaceae	Tree	Fruits	Yes
Kalapapa	*Vitex pinnata*	Verbenaceae	Tree	Blood pressure medication (shoots), wood for canoes and charcoal	No
Suli	*Hedychium coronarium*	Zingiberaceae	Herb	Young shoots (vegetables)	No

∗ See: Noor *et al*. 2015

Non-native, but naturalized

the use of fire for agricultural activities as before, with good village-level control within the customary rules.

Farmers expressed hope that the government could review the fire ban as a policy and allow controlled use of fire, as before. They also expect government officials to provide solutions and guidance on sustainable land management before regulations are imposed on them.

DISCUSSION

In relation to our first research question, our results confirmed a close relationship between a swidden-fallow rotation at some distance from the village, but accessible by canoe, and agroforests on the riverbank closer to the village. Livelihoods centred on the river but interacted with the edges of the peat dome. Land use practices were part of a rich local knowledge of soil and water management transferred from one generation to the next within the customary institutions. The Ngaju Dayak people living in peat landscapes (and peat hydrological units) focused on rivers, riverbanks and non-peat or shallow-peat areas. In the past groups could settle anywhere along the river system that they claimed to be their homelands. They selected locations that were considered to be suitable because of soil fertility, accessibility, ease of management, peat thickness, being free from flooding, and the presence of indicator plants. This knowledge is well kept across generations. Local knowledge in recognizing soil quality with diverse indicator plants is the most important thing learned by local farmers for their agricultural success (Barrios and Trejo 2003, Lima *et al*. 2011, Pauli *et al*. 2012). The Dayak Ngaju people usually choose peaty soil (with insufficient peat depth to be classified as peat soil) or shallow peat for agricultural purposes. The land was used for many years and as a result it contains no peat anymore. Locally this is known as mature peat. However, the definition of mature peat by the Ngaju Dayak tribe is quite different from the one commonly used by researchers. Agus and Subiksa (2008) from the Indonesian Soil Research Institute, for instance, defined mature peat as weathered peat, with its original material unrecognizable, and a colour ranging from dark brown to black, with a fibre content less than 15% when squeezed. A similar definition is used by Agus *et al*. (2011) with the addition of fibre content of less than one-third of all amounts when kneaded. The farmers use an agricultural viewpoint while defining peatland. They always choose land with thin peat layers and prefer soils that contain a layer of clay so that after undergoing soil processing, when the peat will be exhausted, it is still fertile. Farmers believe that mature peat is the best soil phase for agriculture. On the other hand, the researchers differentiate peat maturity based on the weathering process of original material. This indicates that farmers only utilize peaty land, not peatlands. Farmers perpetually consider soil fertility, ease of land management, as well as operational costs. Hence, they have indirectly protected the peat ecosystem, although, due to increased economic pressure, farmers have begun to cultivate peat with a maximum thickness of 50 cm.

Regarding our second question, land use was closely associated with ethnobotanical knowledge of plants as indicators of land quality beyond their roles in livelihoods. While new market-oriented horticulture activities, such as growing watermelon close to the main access road, have become part of the land use system, the adoption of short-cycle tree plantations (sengon) cannot yet be evaluated. The traditional fruits from the agroforests still provide a safety-net. The results obtained in our study villages on the first two questions thus confirmed that most of the traditional human presence in the peat landscapes (and peat hydrological units) has been focussed on the rivers, riverbanks and its non-peat or shallow peat soils. Our results align with the view that when land use for agricultural activities in Kalimantan is to be reconciled with restoration of peat domes (Page *et al*. 2009), a livelihoods perspective is needed, rather than a focus on the peat soils *per se*.

Our findings on the consequences of the 'fire ban' of 2015, the third research question, indicated that it affected existing land use practices and food production by the local communities, and also had implications for local culture and agricultural traditions that could no longer be followed. The existing government programs that were supposed to ease the transition to new ways of farming did not work for the villages where we did the interviews. Temporary off-farm jobs offered by the peatland restoration agency provided some relief, but beyond that migration to the urban areas seemed to be the most attractive alternative option. Such responses call for a further reconsideration of the prevailing policies, as social consequences may not have been fully weighed when the policy was designed. The government support for mechanized 'modern' styles of rice farming did not make this option in the local circumstances.

Forest and land fires in Indonesia in 2015 in Sumatra and Central Kalimantan followed earlier episodes in 1991, 1994 and 1997 that put Indonesia at the receiving end of international criticism (Field *et al*. 2016). The current Indonesian government approach prioritized restoration and rehabilitation of peatlands by establishing the Peat Restoration Agency (BRG – based on PP. No.1 of 2016), to accelerate the recovery of integrated functions of peat hydrology. One of the priorities of BRG activities in Central Kalimantan Province is in Pulang Pisau District, in the form of canal blocking and making bore holes (wells) to have water available to extinguish fire if needed. The aim of these activities is to restore a shallow ground water level and reduce the fire risk in remaining forests and agricultural land. Farmers expressed hope that controlled use of fire for their land clearing system using fire for swiddens can be allowed again, once the landscape has been rewetted. The important element for them is that adat customs can be maintained, including the rituals around land clearing and rice planting, but changing the farming pattern challenges those aspects. There are many benefits from slash and burn land clearing methods, as it is fast and practical, and, most importantly, it reinforces the sense of community through traditional ceremonies. The knowledge and norms of behaviour that prevented swidden fires from escaping may get lost from the local knowledge if it is no longer practised.

As elsewhere, land management in the study area is influenced by socio-economic factors (Takele *et al*. 2015, Handayu *et al*. 2019). Changes in cropping patterns are adjusted to farmers' needs, policies, markets and environmental concerns (El Benni *et al*. 2012, Suprayogo 2017). Shifting cultivation in the tropics, generally has had to convert to swidden rotations with a short fallow period. The efforts of Ngaju Dayak farmers to maintain their agricultural land in the form of agroforest has worked for at least 150 years. They manage 'internal rejuvenation' and gap-level interplanting or *sisipan* management (Joshi *et al*. 2003), avoiding field clearing and replant as is common in tree crop monocultures. These land use practices need to be better understood as part of the peat ecosystem restoration program. The interaction of farmers with peatland over a long time, has provided local knowledge to find indicators of land selection and types of plants species. The success of peatland management is strongly dependent on the skills of farmers and local knowledge. The location of this research along the Kahayan river is close to the Banjarmasin – Palangka Raya road that forms one of the gateways to change. This change has proved to be a threat of damage to the peat ecosystem, with the economic wheels of supposed progress in Pulang Pisau District blocked by the public health disaster of the smoke and haze episodes in years with a long dry season when drained peat is vulnerable to fire risk. For this reason, changes in socio-economic conditions of farmers need to be given attention from the local government, especially when the temporary job opportunities for canal blocking and rewetting provided by BRG are coming to an end. The villagers repeatedly asked us to convey this message to the outside world.

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