Finding Strategies for Peatland Rehabilitation; Agroforestry Systems on Various Types of Peat Depth in Three Villages in Central Kalimantan

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ABSTRACT

Peatland rehabilitation is an urgent need in order to minimize the effects of peat degradation and to support climate change mitigation. However, the rehabilitation of degraded peatlands still faces many obstacles. This study aimed to study the agroforestry system on peatlands applied by traditional communities as an effort to discover a peatland rehabilitation strategy. This research was conducted in the Pilang, Tanjung Taruna, and Kalampangan villages from February to August 2019. The data in this study were obtained through field observations, interviews with the community, and Focus Group Discussion. The data was then synthesized using descriptive statistics. The results of data analysis showed that in the study area, six types of agroforestry systems were found. Communities develop different agroforestry systems at various types of peat depths. Farmers develop vegetable and fruit-based agroforestry on shallow peat, rubber-based agroforestry, annual crops and fruit on medium peat, fruit and rubber forestry plants on deep peat. Most farmers planted endemic species including Rubber *(Havea braziliensis)*, Galam *(Melaleuca leucadendra)* and Gerunggang *(Cratoxylum arborescens)*. The results of this study can be adopted as a peatland rehabilitation strategy since they are in accordance with the socio-culture of the local community and capable to accommodate economic and conservation interests.

Keywords: agroforestry system, peat land rehabilitation, local communities, climate change mitigation.

INTRODUCTION

Climate change mitigation through the conservation of tropical peatlands is drawing increasing attention from the global community. Tropical peatlands store significant amounts of carbon (Jaenicke et al., 2008; Murdiyarso et al., 2010; Warren et al., 2012), estimated at 40 to 90 Gt C (Page et al. 2009; Yu et al. 2010). Peatlands that are degraded and then burned have the potential to emit significant amounts of CO_2. For example, the forest and land fires in Indonesia in 2015 produced emissions of 1.74 Gigatonnes of CO_2. The CO_2 emissions from degraded peatlands range from 1.3 Gt CO_2 eq/year to 1.91 Gt CO_2 eq/year,

depending on the level of degradation (Leifeld and Menichetti, 2018; Leifeld et al., 2019).

Peatland conservation is also important for the sustainability of ecosystem services supply. Peat swamp forest is an important habitat for many endemic animals and plants, regulates the hydrological balance, and provides a variety of products that support people's livelihoods (Cheyne and Macdonald, 2011; Nowak, 2013; Posa et al., 2011; Page et al., 2009; Wich et al., 2008).

One of the important steps in peatland rehabilitation is revegetation. Peatland revegetation begins with restoring the hydrological condition of the peat. Peatland revegetation is intended to support or complement natural succession.

Rehabilitation of peatlands in protected areas can be performed by planting fast-growing species and endemic species as sources of food for wild animals (Giesen and van der Meer, 2009; Graham et al., 2016; Giesen and Sari, 2018).

At buffer zone, near community settlements, peatland rehabilitation must be able to accommodate the community's needs for various products such as fruits, latex, medicinal plants, and firewood. Many land rehabilitation efforts have failed due to technical constraints and a lack of community support (Dudley et al., 2005). Agroforestry offers an alternative solution for peatland rehabilitation due to its capability to accommodate various interests. In general, traditional agroforestry is developed by incorporating traditional knowledge or local wisdom. Maf'tuah et al. (2021) found in their research that agroforestry is suitable as a peatland rehabilitation technique in terms of economy and ecology. Agroforestry can optimally use local resources, low input, and in accordance with the local communities' culture.

Traditional Ecological Knowledge (TEK), which is the foundation for developing traditional agroforestry, constitutes the key to the success of agroforestry. TEK is obtaining increasing attention as an approach to land management and land rehabilitation (Berkes et al., 2000; Covington et al., 1998, Falkowski et al., 2016). In managing traditional agroforestry, TEK can complement, support, or be a guide for ecological restoration. This approach can be regarded as a community reference, where species selection and planting methods are developed based on the traditional knowledge of the community (Charnley et al., 2007; Menzies and Butler, 2006; Parrota and Agnoletti, 2007; Uprety et al., 2017).

The research on peatland rehabilitation based on community practices is still very limited. This study aims to assess the agroforestry system at various types of peat depths applied by local communities. The results of the research might improve the peatland rehabilitation strategies in Central Kalimantan.

METHOD

This research was carried out in three villages, namely the Kalampangan Village, Pilang Village, and Tanjung Taruna Village. The three villages were chosen because their communities manage peatlands with agroforestry systems. The Pilang and Tanjung Taruna villages were chosen to represent the Dayak and Banjar tribes while the Kalampangan village represented the Javanese. Thus, the information obtained from this research represents the diversity of agroforestry systems on peatlands. This research was conducted for six months, from February to August 2019. The data were collected by interviews using open-ended questionnaires and FGD employing a list of questions. In addition, observations were also conducted to obtain planting systems, patterns, and plant species. In total, this study interviewed 90 respondents; each village was represented by 30 respondents. The observations were conducted on 81 agroforestry sites. The data analysis utilized the descriptive statistical method (Sugiyono, 2009). The criteria of peat depth following (Peat Monitoring, 2017); shallow peat 50–100 cm, medium peat 100–200 cm, deep peat 200–200 cm and very deep peat >300 cm.

The Pilang Village is stretched along the Kahayan River Line from North to South with a length of 10 Km, and 18 Km from East to West. Elevation of the Pilang Village is 0–50 meters above sea level an elevation of 0–8°, which is also influenced by river tidal that caused seasonal flood (BRG, 2018). There are two types of soil in the Pilang Village, alluvial soil and peat soil. Alluvial soil stretches along the Kahayan riverbank, which is fertile and suitable for agricultural and community plantations. Peat soil formed at flooded areas, located 1–10 km from the riverbank. Peatland natural vegetation is usually dominated by ferns, Galam, Garunggang, Tumih, and Pulai. The Pilang village has a tropical and humid climate, with a maximum air temperature of 32.5 °C and a minimum average temperature of 22.9 °C. Humidity ranges above 80%. With a wet tropical climate, the Pilang Village has two seasons, namely the rainy season and the dry season. The rainy season starts from October-March with rainfall ranging from 2000–3500 mm/year and the dry season starts in June-September. The main livelihood of the community is rubber farming. In addition, it also carries out sand mining, fishing, and other entrepreneurial activities (BPSa, 2021).

The Tanjung Taruna Village is a village located in the lowlands with an altitude of 0–4 meters above sea level. This village is located on the river banks of the Kahayan River. In addition to the river, the Tanjung Taruna Village also has a lake, which is called Bagantung Lake. It is located in the Tanjung Pusaka Hamlet, about

a 15–20 minute water ride through the Kahayan River from the village government center (BRG, 2018). The Tanjung Taruna Village has a humid climate with temperatures ranging 27–28 °C. This village has two seasons, the rainy season and the dry season. May experienced the highest precipitation reaching 512.1 mm and the lowest in December with 69.9 mm. The land in Tanjung Taruna also consists of mineral soil and peat soil. Residents usually call mineral soil *yellow soil*. The distribution of this alluvial soil is much less than the peat soil in Tanjung Taruna (BPSa, 2021)

The Kalampangan village is a transmigration village founded in 1980. Kalampangan is included in the Palangka Raya District. It is located 18 km north of the city of Palangkaraya, Central Kalimantan Province. Occupying an area of approximately five thousand hectares, this is a successful rural profile on peatland. Dominated by Java ethnic group, the residents of Kalampangan are mostly vegetable farmers. The soil condition and the season in Kalampangan are similar to the Pilang and Tanjung Taruna villages (BPSb, 2021)

RESULTS AND DISCUSSION

Description of agroforestry systems on Peat

Field observations found that the communities in the three study areas applied different agroforestry systems. The interviews with the community revealed that the selection of agroforestry system considered the land conditions including soil type, peat depth, and duration of flooding during the rainy season.

Most of the community settlements in the Pilang and Taruna Jaya villages were built on the riverbank of Sungai Kahayan. This settlement system follows the characteristics of the traditional Dayak community settlement system that builds settlements on the river bank. This is because the river plays an important role as a means of transportation, main water source, and livelihood. The land characteristics in the study areas are also influenced by the river. The land on the river bank is generally mineral soil. The land at this location is relatively fertile because the flood runoff from the river carries a lot of nutrients. Many people use the land at this location for vegetable and fruit gardening. At a distance of 500 meters or 1 km from the riverbank, the land begins to peat. Generally, the farther from the riverbank, the thicker the peat is. On the basis of the distance from the river and the percentage of agroforestry located on peatlands, a description of the agroforestry gardens owned by the respondents is presented in Table 1.

Table 1 above shows that the agroforestry in the Pilang Village is generally located close to settlements and river banks. The community in the Pilang Village is dominated by the Dayak tribe, which maintains their traditional ways of utilization of natural resources and agroforestry management. Their technology and knowledge are largely based on the TEK, culture, and belief system of their ancestors. The villagers prefer building houses by the river and cultivating vegetable agroforestry closed to their settlement. How they manage their garden and selected vegetation is the result of centuries of experience and a product of adaptation to natural conditions. They
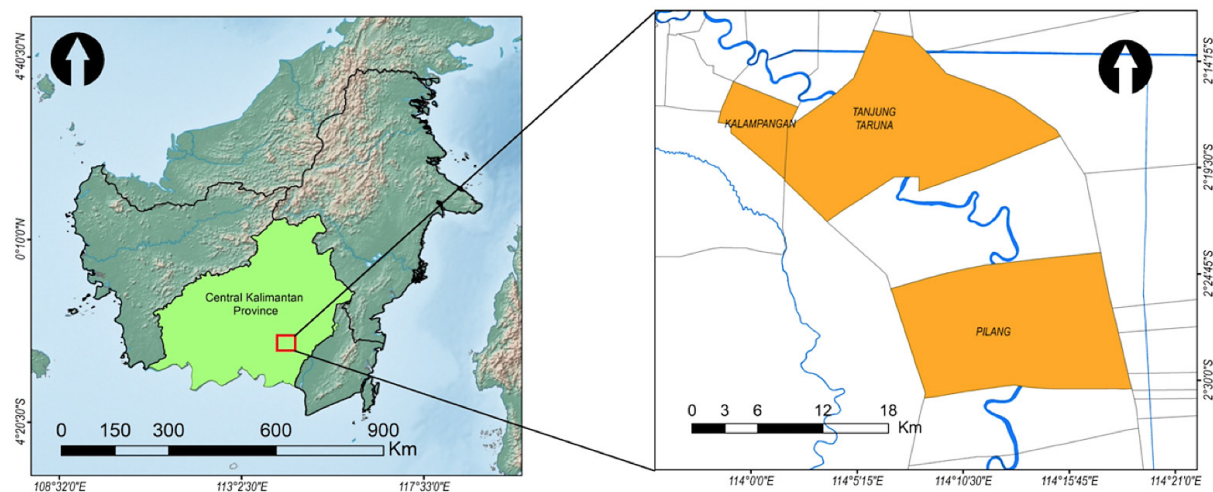

Figure 1. Map of the research location

Table 1. Description of the location of agroforestry in the three research villages

Parameter	Pilang	Taruna Jaya	Kalampangan
Distance from river (km)	1.98	3.06	6.41
Distance from settlement (km)	3.11	2.75	0.63
Average percentage of agroforestry garden that locate on peatland	95.5%	100%	100%
Average percentage of Agroforestry garden that flooded seasonally	8.3%	32.1%	100%
Average percentage of Agroforestry garden located on deep peat	17%	26%	90%
Average percentage of Agroforestry garden located on medium deep peat	64%	73%	3%

manage to utilize vulnerable peatlands to cultivate productive crops without compromising the sustainability aspect. In general, the agroforestry system that their developed is traditional agroforestry with random planting and low input. They do not use chemical fertilizers or pesticides. Most of the plants are allowed to grow naturally along with forest plants.

Conversely, the people of the Kalampangan Village develop their agroforestry on the land around their house. This follows the system of land ownership they have. The Kalampangan Village is a transmigration village that is dominated by the Javanese. Each family is given a house and land allotment around their house of 0.25 square meters. Meanwhile, the community of the Taruna Jaya Village is more diverse, consisting of the Dayak, Banjar, and Javanese. This is reflected in their agroforestry system, some still adopt the traditional system of the Dayak tribe and partly the system of immigrant communities.

The results of interviews with respondents in Taruna Jaya revealed that the condition of the land which is always flooded during the rainy season and burned during the dry season has caused people in Taruna Jaya to be reluctant to manage peatlands and prefer to switch professions to become fishermen. This is different from the respondents in Kalampangan (Javanese Tribe) who process the peat into mature peat so that it is easier for people to choose various types that can be planted. In turn, the respondents in Pilang mostly chose medium peat to be used as a location for farming, especially for the purpose of planting rubber.

Types of agroforestry systems

On the basis of the analysis of the interviews and field observations, in general, the agroforestry on peatlands in the three villages can be divided into six types based on the main commodity and the mixture of its components, namely: (1) rubber and vegetable-based agroforestry, (2) fruit-based agroforestry (3) rubber and fruits based agroforestry (4) palm tree and crops based agroforestry (5) rubber and forestry-based agroforestry (6) forestry and fruits based agroforestry.

Pilang Village agroforestry system

In general, there are three types of peatland agroforestry in the Pilang Village, namely rubber and vegetable-based agroforestry, rubber and fruit-based agroforestry, as well as forestry and fruit-based agroforestry. At different peat depths, farmers develop different agroforestry systems. In other words, the type of plant selected is adjusted to the depth of the peat.

On mineral soil and shallow peat; approximately 3 km from the river, the farmer planted vegetable-based agroforestry. The vegetables grown by residents include banana, cucumber, corn, pumpkin, and eggplant. In turn, the tree species are mostly fruit trees such as mango, rambutan, or water guava. Usually, residents grow vegetables only in the dry season between April to September because this area is flooded in the rainy season. The soil in this area is usually fertile due to floods that carry soil nutrients. Therefore, farmers rarely use fertilizers to grow crops in this shallow peat area. Most products from vegetable-based agroforestry are for subsistence purposes.

In the range of 3–10 km from the riverbank, the peat depth is increasing, ranging from 0.5 to 3 meters depth. In this area, the community develops rubber-based agroforestry with a mixture of fruit trees. Most of the people in the Pilang Village make their main livelihood as rubber farmers and fishing. Rubber tapping is conducted every day and the products are sold to collectors in the village. In order to increase their income, the community also does fishing at the Bagantung lake, Kahayan River, and swamps around the village. In the areas more than 10 km from riverbanks, where generally
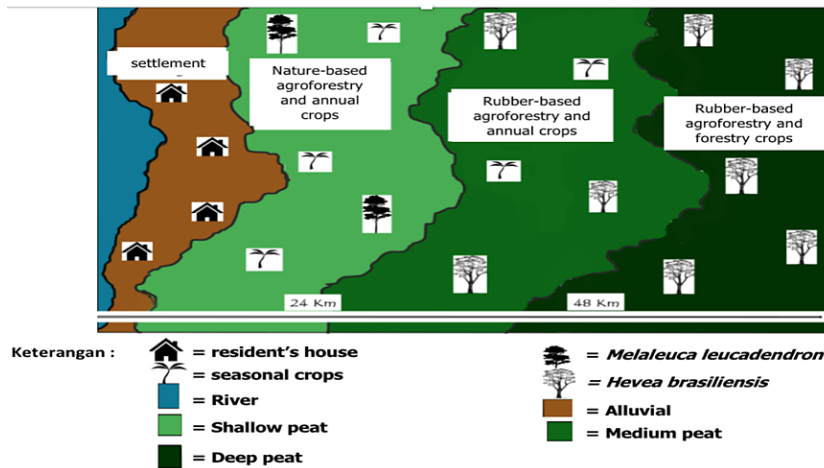
Figure 2. Type of agroforestry system in the Pilang Village

deep peat is formed, farmers plant forest fruit trees and forest trees. The fruits and trees selected in this area are natural species that grow well on deep peatlands such as Cempedak (*Artocarpus integer*) and Rambai (*Baccaurea motleyana*). Meanwhile, the forestry plants include Galam (*Melaleuca leucadendra*), Gerunggang (*Cratoxylon arborescens*), Mahang (*Macaranga triloba*), and Meranti (*Shorea sp.*). The interviews with communities revealed that deep peat is not suitable for agricultural land or intensive plantations. Clearing deep peat areas will only damage the peat and lead to further fires. However, the community can still utilize the deep peat to cultivate forestry trees and fruits.

Agroforestry system in the Tanjung Taruna Village

The agroforestry system in the Tanjung Taruna Village at various types of peat depth includes crops based agroforestry, rubber and crops based and agroforestry and also rubber and forestry tree-based agroforestry.

The peatland agroforestry system in the Taruna Jaya Village is similar to the agroforestry system in the Pilang Village. Annual crops are planted on shallow peat areas. The people in this village do not grow vegetables because the area in this village is often flooded. Thus, instead they grow seasonal crops such as pineapple and bananas which are more tolerant to flood. On medium peat, the community applies an agroforestry
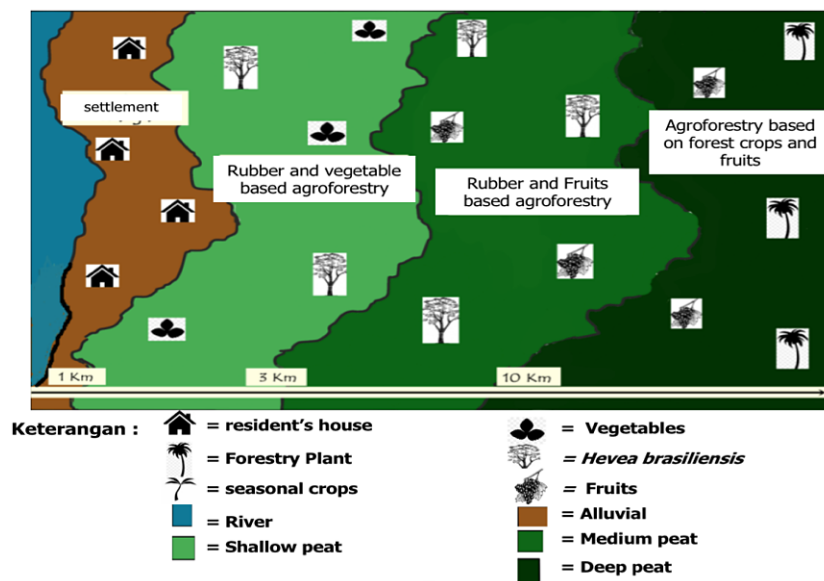

Figure 3. Type of agroforestry system in the Tanjung Taruna Village

system based on rubber and seasonal crops; meanwhile, in deep peat they planted rubber and forestry plants such as galam (*Melaleuca leucadendron*) and gerunggang (*Cratoxylum arborescens*). Galam and gerunggang are two endemic species that can grow well on peatlands and even on scar burnt lands. This endemic species are tolerant to acidity of peatland. People sell galam wood as construction support with prices ranging Rp. 8000–15,000. Rubber is planted in rows and forestry plants grow naturally between rubber.

Agroforestry system in the Kalampangan Village

The agroforestry system in the Kalampangan village is different from the two previous villages. The settlements in this village are placed on deep peat and close to the Trans-Kalimantan road. This village applied more intensive farming systems with chemical fertilizer and treatment to reduce the acidity of peat.

On the basis of Figure 3, in general, the types of agroforestry systems in the Kalampangan village are as follows: vegetable gardens (seasonal plants) on shallow peat, agroforestry based on fruits, and seasonal crops on medium depth, and agroforestry based on forestry crops, fruits, and vegetables on deep peat. The farmers in this village manage the peatland around their houses to cultivate vegetables. In contrast to the Pilang and Taruna Jaya villages which cultivate vegetables for subsistence needs, the vegetables from the Kalampangan Village are sold to the markets in Palangka Raya. The Kalampangan Village is

known as a producer of vegetables and fruit for the City of Palangka Raya and its surroundings. In the locations farther from housing, farmers develop agroforestry based on fruits and vegetables. Peatland management in the Kalampangan Village is relatively intensive. In order to reduce the acidity of peatlands, they apply ameliorant in the form of calcium carbonate ($CaCO_3$) and also apply mechanical treatment to increase the decomposition of peat.

Dominant plant types in Peatland Agroforestry Kebun

The selection of plant species is an important aspect for farmers because this is the key factor that determines the level of success. The results of the interviews showed that the farmers in the Pilang and Taruna Jaya villages chose the type of plant based on hereditary habits. The knowledge of the types of plants that can grow on peatlands they obtained from their parents or predecessors. The experience of living on peatlands teaches them that thick peat is not suitable for growing crops. They usually plant thick peat with forestry plants that are endemic to the peat ecosystem that tolerant to soil acidity. Fruit plants are usually planted on peat of medium depth. The preference of plants on peatlands is different from that of the Kalampangan Village. This village is dominated by the Javanese who are immigrants and have more advanced farming techniques. The farmers in the Kalampangan Village cultivate vegetable crops at various types of peat depth. The vegetables produced in the Kalampangan Village are
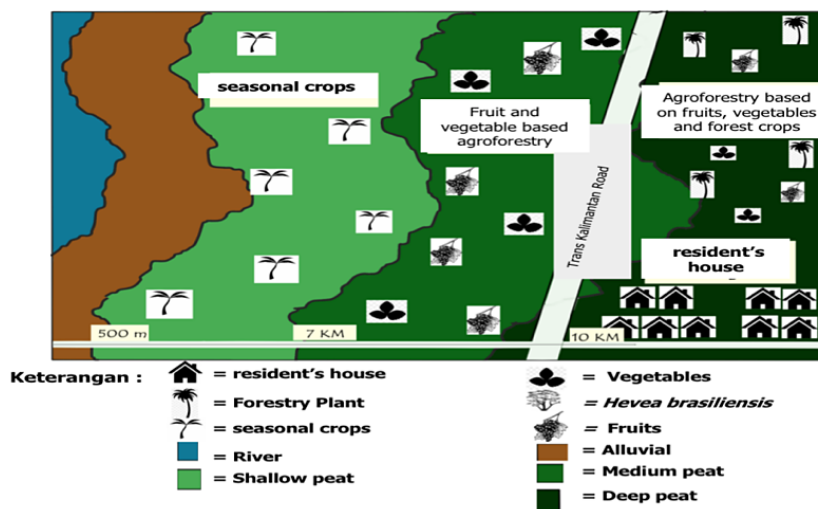

Figure 4. Type of agroforestry system in the Kalampangan Village

mostly for sale. In detail, the most dominant local plant species owned by respondents in peatland agroforestry gardens in the three villages are presented in Table 2

This study also found that there are nine uses of agroforestry products including building materials, food sources, medicines, natural dyes, handicrafts, animal feed, fish feed, culture, adhesives, and others. Most of the products from agroforestry are utilized as a food source. This also indicates that the agroforestry system can support the food security of the surrounding communities. Food security is an essential issue that is one of the priorities of climate change adaptation programs (Afentina et al, 2021). The cultivation of rubber plants is one of the livelihoods of the people in the Pilang and Taruna Jaya villages. The community sold rubber for Rp. 7000–10,000 per kilogram. The rubber cultivated by the community is local rubber which has low productivity but is adaptive to the local conditions. Although rubber is the main commodity in their agroforestry, the income from it is not sufficient. Farmers do not have a bargaining position in determining rubber prices. This is where the advantages of the agroforestry system come into play. Other products from rubber-based agroforestry systems, such as fruit and construction wood, can provide additional income.

The Table 3 shows that the most dominant utilization is food sources. This also indicates that agroforestry can support community food security efforts in the face of climate change and other ecological disasters (Afentina et al., 2021). The food plants cultivated by farmers have various cycles: short, medium, and long cycles.

Vegetables such as spinach and tomatoes have a short cycle of about 3–4 months. Thus, they provide short-term income. The fruit such as oranges and mango that are harvested annually provide medium-term income.

Furthermore, forestry trees such as galam and gerunggang provide long-term income. To conclude, the peatland agroforestry developed by the community provides sustainable income. This can be taken into account in choosing the peatland rehabilitation strategies.

Traditional peatland agroforestry developed by the community can constitute an alternative method of peatland rehabilitation because this system has been proven sustainable and adaptable on peatlands without bringing devastating effects on peatlands. Furthermore, this system is developed based on local wisdom and traditional knowledge so that it is suitable for the socio-cultural conditions of the people living around peatlands. Thus it will minimize the rejection by the community and increase awareness.

From the economic point of view, this traditional agroforestry system is suitable to the economic condition of the locals which have limited capital. Farmers do not require spending money on chemical fertilizers, pesticides, or modern equipment. This system is environmentally friendly and this character is an important factor considering the vulnerability of peatland. The finding of the research gives convincing evidence to governments, NGOs (Non-government organizations) and, other stakeholders to adopt this traditional agroforestry to rehabilitate degraded peatland.

Table 2. Dominant plant species in agroforestry gardens in the Pilang, Taruna Jaya and Kalampangan villages

Type of soil	Dominant plant species		
	Pilang	Taruna Jaya	Kalampangan
Mineral soial	Karet *(Havea brasiliensis)*	-	-
Shallow peat	Durian *(Durio zibethinus)*; Karet *(Havea brasiliensis)*; Kangkung *(Ipomoea aquatica)*	Galam *(Melaleuca leucadendra)* Jagung *(Zea mays)*; Kacang panjang *(Vigna unguiculata ssp.)*; Padi *(Oryza sativa)*	Buah Naga *(Hylocereus undatus)*; Daun bawang *(Allium sp.)*; Sengon *(Albizia chinensis)*
Medium peat	Cempedak *(Artocarpus integer)*; Rambai *(Baccaurea motleyana)*' Karet *(Havea brasiliensis)*	Jagung *(Zea mays)*; Karet *(Havea brasiliensis)*;	Daun bawang *(Allium sp.)*; Lombok *(Capsicum frutescens)*; Terong *(Solanum melongena)*; Timun *(Cucumis sativus)*; Tomat *(Solanum lycopersicum)*
Deep peat	Karet *(Havea brasiliensis)*; Cempedak *(Artocarpus integer)*; Galam *(Melaleuca leucadendra)*	Galam *(Melaleuca leucadendra)*; Gerunggang *(Cratoxylon arborescens)*; Karet *(Havea brasiliensis)*	Buah Naga *(Hylocereus undatus)*; Daun bawang *(Allium sp.)*; Jagung *(Zea mays)*

Table 3. Types of plants in each type of utilization

Type of utilization	Type of plant	
	Crops	Annual
Food source	• Spinach *(Amaranthus spp.)* • Green onion *(Allium fistulosum)* • Gambas *(Luffa acutangula)* • Sweet potato *(Dioscorea esculenta)* • Green bean *(Vigma unguiculta ssp.)* • Water spinach *(Ipomoea aquatica)* • Taro *(Caladium sp.)* • Basil *(Ocimum x citriodorum)* • Pumkin *(Cucurbita sp.)* • Chili *(Capsucum fritescens)* • Big Chili *(Capsucum annuum L)* • Melon *(Cucumis melo)* • Pineapples *(Ananas comosus)* • Padi *(Oryza sativa)* • Sawi *(Brassica chinensis Parachinensis)* • Sawo *(Manilkara zapota)* • Sayur Manis *(Brassica rapa)* • Celery *(Apium graveolens)* • Water melon *(Citrullus lanatus)* • Casava *(Manihot esculenta)* • Strobery *(Fragaria xananassa)* • Egg pnat *(Solanum melongena)* • Sour egg plant *(Solanum ferox)* • Cucumber *(Cucumis sativus)* • Tomato *(Solanum lycopersicum)* • Waluh putih *(Lagenaria siceraria)*	• Bamboo *(Bambuseae)* • Avocado *(Persea americana)* • Star Fruit *(Averrhoa carambola)* • Dragon fruit *(Hylocereus undatus* • Cempedak *(Artocarpus integer)* • Durian *(Durio zibethinus*) • Fragrance Mango • Corn *(Zea mays)* • Guava *(Psidium guajava)* • Orange *(Citrus)* • JackFruit *(Artocarpus heterophyllus)* • Leci *(Dimocarpus longan)* • Mango *(Mangifera indica L.)* • Paken/ Durian kuning *(Durio kutenjensis)* • Petai *(Parkia speciosa)* • Banana *(Musa paradisiaca)* • Rambutan *(Nephelium lappeceum)*
Construction material	-	• Galam *(Melaleuca leucadendron)* • Gerunggang *(Cratoxylum arborescens)* • Jabon *(Neolamarckia cadamba)* • Mahang *(Macaranga triloba)* • Meranti *(Shorea sp.)* • Rattan *(Calamus sp.)* • Sagu *(Metroxylon sagu Rottb.)* • Sengon *(Albizia chinensis)* • Sungkai *(Peronema cenescens)* • Tarantang *(Campnosperma sp.)* • Tumih *(Combretocarpus rotundatus)*
Other utilization	-	• Rubber *(Hevea brasiliensis)* • Jelutung *(Dyera costulata)* • Rotan *(Calamus sp.)* • Sagu *(Metroxylon sagu Rottb.)*

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