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Dito Septiadi

*Agroforestry-based Paludiculture*

# AGROFORESTRY-BASED PALUDICULTURE COMPOSITIONS IN INDONESIAN TROPICAL PEATLANDS

**Dito Septiadi Marony Sitepu*, Bas Tinhout**, and Andre van Amstel*****

*MSc Student of Wageningen University and Research Centre, Department of Environmental Sciences

**Wetlands International the Netherlands

***Wageningen University and Research Centre, Environmental Systems Analysis Group

**Abstract**. *Agroforestry-based paludiculture in peatland requires rewetting of drained peatlands and the potential to offer sustainable economic returns to strengthen rural livelihoods. Composition of agroforestry-based paludiculture delivers varied ecosystem services, products as well as environmental impact reduction. There is still a lack of knowledge about the agroforestry composition on rewetted peatlands. The objective of this study is to assess different compositions of agroforestry-based paludiculture for sustainable peatland management in Indonesian tropical peatland. The study methods are paludiculture species identification, provisioning services and valuation, stakeholder analysis, scenario analysis, and multi-criteria analysis. 16 potential paludiculture species were identified, namely Manggis (Garcinia mangostana), Rambutan (Nephelium lappaceum.), Kangkong (Ipomoea aquatica Forsk.), Bitter melon (Momordia charantia), Sagu (Metroxylon sagu Rottb.), Jelutung (Dyera costulata), Rotan (Calamus sp.), Gelam (Melaleuca cajuputi Powell), Gemor (Nothaphoebe coriacea), Ramin (Gonystylus bancanus), Tengkawang (Shorea spp.), Kemiri (Aleurites moluccana), Sindur (Sindora velutina Baker), Tuwa areuy (Derris trifoliata), Areuy carulang (Spatholobus ferrugineus), Ekor kucing (Uraria crinita). Three scenarios are developed: economic focus, biodiversity conservation focus, and nitrogen fixation focus. There are at least 14 primary stakeholders in the Indonesian peatlands. Private sectors and Governments are more aligned with economic focus. NGOs and Research Institutes are more aligned with biodiversity conservation focus scenario. Civil societies are more aligned with nitrogen fixation scenario. The result of the multi-criteria analysis showed that the economic focus scenario is the most recommended option for agroforestry-based paludiculture, and biodiversity conservation focus can be the alternative scenario. Hence, these two scenarios can go hand in hand for sustainable peatland management. The concept of agroforestry-based paludiculture can change the social dynamics around the peatlands. Further field experiments are urged to investigate the possibility and probability of these agroforestry-based paludiculture species.*

## 1. INTRODUCTION

### 1.1 Issues related to peatlands in Indonesia

Indonesia has around 22 million hectares of peatlands, mainly located in Kalimantan, Sumatera and Papua. These constitute a large portion of all tropical peatlands (Van Beukering et al., 2008). In contrast with other tropical peatlands outside Southeast Asia, Indonesian peatlands are largely degraded. The peatland degradation is mainly caused by human activities to drain peatlands for palm oil and pulp wood (e.g. *Acacia spp.*) plantations using drainage canals. Deforestation and conversion to plantation, illegal logging, and off-site drainage impacts remain a continuing threat to intact Peat Swamp Forests (PSFs) (Tata and Susmianto, 2016). Peatland drainage lowers the water table and dries out the soil, causing oxidation of the peatland. This leads to the fact that Indonesia is the third highest emitter of $CO_2$ emissions in the world (Hooijer et al., 2006). Drained peatland is susceptible to fires during dry periods leading to more GHG emissions, haze and causing negative health effects and economic losses. A study shows the impact of peat fires in degraded peatland is estimated to be approximately 1,400 $MtCO_2$/year for 1997-2006 (Hooijer et al., 2006). The degraded peatland leads to peat oxidation, loss of carbon and compaction of the soil cause peatland subsidence, and flooding (Hooijer et al., 2012), also biodiversity loss, including endemic species such as the Bornean Orang-utan (*Pongo pygmaeus*) (Ancrenaz et al., 2016).

A recent study in Kampar peatland (Riau, Indonesia) shows that acacia plantations are projected to result in drainability and flooding problems of 76% of the total area with subsidence rate of 3.5 cm/year in 25 years. Furthermore, palm oil is dealing with flooding problems of almost 67% of the entire area for industrial plantations and 79% of the entire area for smallholder plantations with subsidence rate of 3.5 cm/year in 25 years (Sumarga et al., 2016); (Hooijer et al., 2015b). According to (Hooijer et al., 2015a), as peatland surface subsides, it will reach an irreversible point where flooding events will always occur.

Another study in Borneo case, peat forest fires cause additional serious decline of the Orangutan population at least once every decade. The population of Bornean Orangutans reduced by more than 60% in 1950-2010 and it is predicted the number will be further reduced by 22% in 2010-2025 (Ancrenaz et al., 2016). In 2015, the raging forest fires in Borneo threatened one third of the world's remaining wild orang-utans. The effects of smoke inhalation on animals are expected to make them sick and unable to feed (Vidal, 2015), leading to the death and biodiversity loss (Ancrenaz et al., 2016).

Another case about the women's role in Indonesian peatland. As stated by Murdiyarso et al. (2005), sustainable development requires gender equality in daily activities on peatland areas. In fact, women actively participate on forest fire fighting until informal advocacy to companies that have forest concessions. However, they often aren't involved in the decision-making process in peatland restoration and rehabilitation; hence their interests and aspirations aren't taken into account (Women Research Institute, 2014).

### 1.2 Agroforestry-based paludiculture

Degraded peatland will need to be rewetted to a natural state to prevent further loss of carbon. According to Wetlands International (2016), rewetting and the use of peatland-adapted economically interesting species (paludiculture) offers an incentive for rewetting already degraded peatland and sustains its ecosystem services. A shift from drainage-based agriculture to paludiculture is required to reduce environmental problems. Priority areas are areas close to drainage base and buffer zones around PSF that enhances their protection.

One of the most promising forms of paludiculture is agroforestry. Agroforestry defines as a condition where the area is planted with mixed tree and crop species (Hairiah et al., 2003). Agroforestry-based paludiculture on peatland mitigates the environmental issues, restores the peatland functioning and can provide food for local livelihoods. The agroforestry-based paludiculture concept is suitable for areas where local people and villages depend on the peatland for their livelihood as well as for a buffer from fires that started in drained areas and as a hydrological buffer around remaining PSF. Moreover, this concept supports peatland restoration and rehabilitation by providing tree and crop with high economic value for the replacement of smallholder palm oil and pulp wood plantations. Thus, agroforestry-based paludiculture has an important role as part of a restoration and rehabilitation effort of degraded peatland (Widayati, 2016).

### 1.3 The advantages of agroforestry-based paludiculture in peatland

Agroforestry-based paludiculture provides both economic and environmental benefits. As an economic benefit, agroforestry-based paludiculture diversifies crops; hence reduces dependence on a single yield (Godoy and Feaw, 1991). For its environmental impact, according to (Suwarno et al., 2016), agroforestry-based paludiculture releases $CO_2$ emission (ton/ha/year) lower than oil palm plantation in peatland, but it strongly depends on the composition of the agroforestry. Agroforestry provides service, namely the habitat for variety of wild species (Walter and Pierce, 2008). Thus, agroforestry-based paludiculture can also provide this service in peatland. Moreover, agroforestry-based paludiculture can prevent the traditional slash-and-burn activities by providing more sustainable alternative species than palm oil and acacia plantation; thus the rate of peatland conversion of natural habitat can be reduced (Sumarga et al., 2016). Agroforestry-based paludiculture provides a composition of trees and plants that can enrich the peat soil. By conducting the appropriate tree and crop management, the peat soil nutrient content can be richer than monoculture paludiculture (Victoria et al., 2012).

A study shows that Agroforestry-based paludiculture can also have significant role in biodiversity conservation, especially by promoting native tree species that are suitable for sustainable peatland management in mix trees and crops system, minimizing the chances of pest and disease outbreaks, and becoming a windbreak (Kindt et al., 2005). Moreover, paludiculture consist of legume species; thus agroforestry-based paludiculture can provide nitrogen fixation in the peatland. According to Biswas and Gresshoff (2014), legumes have a big contribution to soil fertility due to the symbiosis they establish with the nitrogen-fixing bacteria. This highers the N in the soil that benefits nitrogen-limited crops which often produce protein for animal and human consumption.

### 1.4 Issues related to agroforestry-based paludiculture in Indonesian peatland

In Indonesia, agroforestry system has already been quite well-known for a long time (ICRAF, n.d.). Agroforestry-based paludiculture can provide varied commodities, ecosystem services as well as reducing environmental impacts of business as usual peatland management (Abebe, 2005). A detailed analysis of the diversity, species compositions, and ecosystem services is still missing. This analysis will identify ecological and economic benefits; then it will eventually assess how it addresses issues before rewetting.

Only a few studies are published about paludiculture species. According to (Tata and Susmianto, 2016), there are already nine native paludiculture species that have been cultivated traditionally in peatland. Another study by Giesen (2015a) shows that there are at least 81 suitable paludiculture species to be developed in Indonesian peatland. Giesen (2015b) analysis of *Melaleuca cajuputi Powell* as a recommended paludiculture commodity since it provides economic and ecological benefits in peatland. Suwarno (2017) developed the establishment of village forest under paludiculture's approach in Mendawai Village, Central Kalimantan. Tata et al. (2016) analysed the domestication of *Dyera polyphylla* (Jelutung) in peatland agroforestry systems in Jambi, Indonesia. Sonderegger and Lanting (2011) explored the challenge of sustainable peatland farming in Padang Island, Sumatra by adapting the notion of seeking a balance between the three dimensions of sustainability; the economic, the social, and the ecological one. (Joosten et al., 2012) provided the guidance for the restoration and sustainable use of peatland using paludiculture.

Other studies in Europe and United States provide a broad range of payment for paludiculture marketing (wet peatland and forestry) that can stimulate peatland rewetting and conserve peatland ecosystem functions, such as sale of biomass, agri-climate and agri-environmental funding programmes, framework contracts for nature conservation, water abstraction charges, and carbon credits (Wichtmann et al., 2016). However, such payments are not available yet in Indonesia since the market for paludiculture produces still in the development phase (Giesen, n.d.). Moreover, Tata et al. Tata et al. (2016) analysis of *Dyera costulata* as agroforestry commodity in peatland. However, there is no evidence of *Dyera costulata* can be mixed with other paludiculture species. It is still integrated with existing farming systems (such as coffee, rubber, oil palm, and shrubs). Thus, there is still a lack of knowledge about the agroforestry composition that is only using paludiculture species.

This study will analyse paludiculture species based on Giesen (2015a) and Tata and Susmianto (2016) and their primary ecosystem services. Then, the possible compositions for agroforestry-based paludiculture will be assessed by using scenario analysis. By comparing all possible compositions, the Multi-Criteria Analysis will determine the best agroforestry composition of paludiculture. In the end, this study will recommend the possible agroforestry composition for sustainable peatland management.

## 2. RESEARCH OBJECTIVE

The objective of this study is to assess different composition of agroforestry-based paludiculture for sustainable peatland management in Indonesian tropical peatland. This research objective will be analysed in sub-research questions:

- What are the suitable paludiculture species to be cultivated in Indonesian peatland in term of ecological and economic aspect?
- What are the provisioning services of paludiculture species in Indonesian tropical peatland, and what are their values?
- What are the feasible commodity compositions for agroforestry-based paludiculture?
- Who are the key stakeholders and what is the most preferred scenario with regard to agroforestry composition in paludiculture?

## 3. METHODOLOGY

These study methods are adapted from Sukhdev et al. (2010) recommendation on the following most important points to be studied: (1) Provisioning services, including the selection and description of the direct services relevant for paludiculture species; (2) Valuation, that related to access of the environmental and economic importance of the ecosystem services; (3) Stakeholder Analysis; (4) Scenario Analysis; (5) Multi-Criteria Analysis.

### 3.1 Study Site

This study is located in peatland restoration areas in Indonesia. The Republic of Indonesia is an archipelago stretching along the equator including 13,446 islands. It lies between 6$^{o}$N and 11$^{o}$N latitudes and between 95$^{o}$E and 141$^{o}$E. Indonesia has approximately 2,000,000 km$^2$ of land area and 3,000,000 km$^2$ of sea area. Indonesia is located between Asian Continent and Australian Continent, and between the Indian Ocean and the Pacific Ocean. Indonesia has boundaries with Malaysia, Singapore, Vietnam, Philippines, Thailand, Palau, and the South China Sea in the North; Australia, Timor Leste and the Indian Ocean in the South; Papua New Guinea and the Pacific Ocean in the East; Pacific Ocean in the West. The average temperature in Indonesia is around 27 degrees Celsius with 80% of humidity. The number of precipitations can vary from 1,000-3,000 per years (BPS, 2016b).

Figure 1 illustrates Indonesian peatlands that are mainly located in Kalimantan, Sumatera, and Papua. The largest peatland area is located in Sumatera with 7,230,230 ha, and followed by Kalimantan with 5,781,720 ha (Miettinen et al., 2016).

Figure 1 Peatland distribution in Indonesia

### 3.2 Paludiculture species identification

This study identifies some suitable paludiculture species to be cultivated in Indonesian peatland. The criteria of suitable are defined into two aspects: ecological aspects and economic aspects.

Regarding the ecological aspects, this study analyses: Water Table Depth (WTD), Soil pH, and Peat depth. First, Water Table Depth is always a range as in a natural stage this fluctuates but has high influence to crop growth and will determine if the cultivation is paludiculture. Every paludiculture species has its own particular Water Table Depth range for optimal growth and development (Bierkens, 1998). Second, optimal soil pH for each paludiculture species is an important variable that defines species suitability (Utomo, 2010). Peat depth is also important to determine the suitability of the plant species in the peatland (Chotimah, 2002).

Regarding economic aspects, there are three criteria to be analysed adapted from (Suwarno et al., 2016), namely the type of paludiculture product, market price and market availability for the crop. There are many types of products as they can vary from fruit, timber, seeds, latex, etc. (Daryono, 2009). Every paludiculture species has a particular economic value depending on the product they deliver and what the market is willing to pay for it. The market availability determines whether the product has a local market or becomes an export goods. Therefore, these six criteria are influential in determining which paludiculture species are preferred.

## 3.3 Provisioning services and Valuation

Provisioning services are identified on a species level as well as on the level of agroforestry-based paludiculture composition. The value of the provisioning services is calculated, using various market methods. Based on the Total Economic Value (TEV) framework (IUCN et al., 2004), the provisioning services can be directly used, and are easy to quantify as the market values are available. This analysis will focus on food, timber, non-timber forest products (NTFPs) and recreation (being a non-consumptive direct use).

## 3.4 Scenario Analysis

This study will integrate some potential paludiculture species in agroforestry peatland system. To compare the compositions of agroforestry-based paludiculture, three combinations of paludiculture species, representing different scenarios are prepared and analysed:

**Scenario 1 (Economic focus)**

The agroforestry-based paludiculture is composed of a mix of species with high economic value that require a short and medium time to reach maturity and start delivering crop. These short-term paludiculture species need less than five years to reach full production capacity. Moreover, the medium-term paludiculture species require less than 10 years before delivering crop or being harvested. This scenario is assumed to provide sustainable high economic income from various products, such as starch, wood, latex, rattan, and oil.

**Scenario 2 (Biodiversity conservation focus)**

This scenario is adapted from Jose (2009). This agroforestry-based paludiculture is composed of species with high potential for biodiversity conservation by providing food and shelter for umbrella species groups that occur in peatlands. In this study, Orang-utan is assumed to be the umbrella species because of its high habitat requirements that will conserve many other species (Dellatore, 2007, Simberloff, 1998). This scenario assumed to have a minimal level of human disturbance, to have a minimal management activity, and to provide food/nutrients for other species. Moreover, this scenario only presents NTFPs, such as fruits, incense, and nuts.

**Scenario 3 (Nitrogen fixation focus)**

This scenario is adapted from Jose (2009). This agroforestry-based paludiculture has an important role in enhancing and maintaining soil productivity and sustainability. The scenario is a combination of trees and crops that can fix nitrogen biologically in the peat soil and nitrogen-limited species that have a high productivity with high levels of nitrogen. This type of agroforestry-based paludiculture provides the production of agriculture crops (such as vegetables) and legumes (family Leguminosae or Fabaceae). It is assumed that this scenario can maintain the amount of nitrogen in the peatland by combining various ecosystem services, such as nitrogen-fixing plants and vegetables.

## 3.5 Stakeholder analysis

A multitude of actors has a stake in deciding on agroforestry composition options. Some of these actors have more influence over the decision than others. In this section, the stakeholders will be analysed, to gain insight into their various interests, perspectives and values. These insights are the critical input for the formulation of criteria and weighting of these criteria in the Multi-Criteria Analysis (MCA) (Section 3.6). A further analysis of the relative (formal and informal) influence of the stakeholders in the decision-making process is direct input for the weighting of the stakeholder voices in the MCA.

Regarding agroforestry compositions, the following stakeholder groups were identified:

- Private sectors: Palm Oil (PO) companies and Pulp and Paper (P&P) companies.

- Governments: BRG (Peat Restoration Agency) and Ministry of Environment and Forestry).
- Research Institutes and NGOs: International and local conservation NGOs, Research Institutes, and University.
- Civil Societies: NTFP collectors, local communities, and smallholder oil palm plantations.

### 3.6 Multi- Criteria Analysis (MCA)

To incorporate qualitative criteria, and to account for the difference in values between the stakeholders, the ecosystems services analysis is followed up with a MCA. First, criteria are formulated, reflecting the issues the various stakeholders would value in a solution.

Then, the performance of the three scenarios is scored against these criteria, followed by a weighting of the criteria. This weighting is carried out in two steps: first, each of the stakeholders identified earlier assigns a weighting to each criterion (this weighting is done by using literature review). Second, stakeholders are assigned a weight in line with their likely influence on the decision. The last step is to calculate the total scores of the various scenarios by multiplying the weights and the scores, and adding up the weighted scores for each scenario.

## 4. RESULT

### 4.1. Result of Paludiculture Identification and ecosystem services analysis

Based on three scenarios in Section 3.4, We identified 16 potential paludiculture species in the Indonesia peatland, namely Manggis (*Garcinia mangostana*), Rambutan (*Nephelium lappaceum*), Kangkong (*Ipomoea aquatica Forsk.*), Bitter melon (*Momordia charantia*), Sagu (*Metroxylon sagu Rottb.*), Jelutung (*Dyera costulata*), Rotan (*Calamus sp.*), Gelam (*Melaleuca cajuputi Powell*), Gemor (*Nothaphoebe coriacea*), Ramin (*Gonystylus bancanus*), Tengkawang (*Shorea spp.*), Kemiri (*Aleurites moluccana*), Sindur (*Sindora velutina Baker*), Tuwa areuy (*Derris trifoliata*), Areuy carulang (*Spatholobus ferrugineus*), Ekor kucing (*Uraria crinita*). The identification and characteristics of these potential species were analysed based on ecological and economic aspects from Section 3.2. Table 1 and Table 2 show the summary of the primary findings. Annex 1 and 2 present the entire findings from these 16 paludiculture species.

Table 1. Identification of paludiculture species based on ecological aspects

| Latin name | WTD (cm) | Soil PH | Peat Depth (cm) |
|---|---|---|---|
| *Garcinia mangostana* | 30-70 | 5-7 | 50-200 |
| *Nephelium lappaceum* | 30-70 | 4-6.5 | 20-230 |
| *Ipomoea aquatica Forsk.* | 30-60 | Unknown | 50-200 |
| *Momordia charantia* | 30-60 | 6-6.7 | 50-200 |
| *Metroxylon sagu Rottb.* | 20-40 | 4-5 | 0-300 |
| *Dyera costulata* | 0-50 | 3-4 | 100-300 |
| *Calamus sp.* | Unknown | 4.4-5.14 | Unknown |
| *Melaleuca cajuputi Powell* | Unknown | 3.1-3.9 | 0-300 |
| *Nothaphoebe coriacea* | Unknown | 3-4 | 0-300 |
| *Gonystylus bancanus* | 0-50 | 4-5.1 | 30-180 |
| *Shorea spp.* | 0-50 | 4.5-5.5 | 30-300 |
| *Aleurites moluccana* | Unknown | 5-8 | Unknown |
| *Sindora velutina Baker* | Unknown | 2.7-4.0 | 5-10 |
| *Derris trifoliata* | Unknown | 4.5-6 | Unknown |
| *Spatholobus ferrugineus* | Unknown | Unknown | Unknown |
| *Uraria crinita* | Unknown | Unknown | Unknown |

Table 2. Identification of paludiculture species based on economic aspects

| Latin name | Product | Market price (Rupiah/ha/year) | Market availability |
|---|---|---|---|
| *Garcinia mangostana* | Fruit | 60,000,000 | Export |
| *Nephelium lappaceum* | Fruit | 25,173,610 | Export |
| *Ipomoea aquatica Forsk.* | Vegetable | 10,261,431 | Local |
| *Momordia charantia* | Vegetable | 15,652,000 | Export |
| *Metroxylon sagu Rottb.* | Starch (non-seed) | 37,547,548 | Local |
| *Dyera costulata* | Latex | 8,926,608 | Export |
| *Calamus sp.* | Rattan | 7,000,000 | Export |
| *Melaleuca cajuputi Powell* | Essential oil and timber | 22,412,650 | Export |
| *Nothaphoebe coriacea* | Incense bark | 4,166,667 | Export |
| *Gonystylus bancanus* | Incense | 1,665,577 | Export |
| *Shorea spp.* | Oil bearing illipe nut | 2,812,500 | Export |
| *Aleurites moluccana* | Edible nut | 4,737,070 | Local |
| *Sindora velutina Baker* | Resin | Unknown | Unknown |
| *Derris trifoliata* | Binding material | Unknown | Unknown |
| *Spatholobus ferrugineus* | Binding material | Unknown | Unknown |
| *Uraria crinita* | Medicine | Unknown | Unknown |

### 4.2. Result of Scenario Analysis

*Economic focus scenario*

Based on the assumption in Section 3.4, we categorised six potential paludiculture species into this scenario, namely *Garcinia mangostana, Metroxylon sagu Rottb.*, *Nephelium lappaceum, Dyera costulata, Calamus sp.*, and *Melaleuca cajuputi Powell*. These species have high economic value products (see Table 2) and several harvesting-cycles from fast maturing to slow maturing species see table 3.

Table 3. Harvesting cycle of six paludiculture species

| Latin name | Market price (Rupiah/ha/ year) | First harvest (year) | Harvesting cycle (after first harvest) |
|---|---|---|---|
| *Garcinia mangostana* | 60,000,000 | 6 | Each year |
| *Metroxylon sagu Rottb.* | 37,547,548 | 6 | Each year |
| *Nephelium lappaceum* | 25,173,610 | 8-10 | Each year |
| *Melaleuca cajuputi Powell* | 22,412,650 | 3-4 | Each year |
| *Dyera costulata* | 8,926,608 | 7 | Each year |
| *Calamus sp.* | 7,000,000 | 3 | Once |

The scenario can generate high income, daily food as well as long-term economic security for local communities. The starch from *Metroxylon sagu Rottb.*, for instance, are become a major staple food in some areas in Indonesia. *Garcinia mangostana* and *Nephelium lappaceum* provide fruits that are edible or can be sold as additional income. Moreover, *Dyera costulata*, *Calamus sp.*, and *Melaleuca cajuputi Powell* generate high income from their NTFPs.

*Biodiversity conservation focus scenario*

We categorised six potential paludiculture species for this biodiversity conservation focus scenario, namely *Garcinia mangostana*, *Nephelium lappaceum*, *Shorea spp.*, *Aleurites moluccana*, *Nothaphoebe coriacea*, and *Gonystylus bancanus*. The fruits produced by *Garcinia mangostana* and *Nephelium lappaceum* are edible for Orang-utan and human. To highlight, orangutans consume about 27.4% of fruit production; thus the economic income from fruit species will be decreased by 27.4% of the total fruit productions in this scenario (Campbell-Smith et al., 2012). However, this creates a potential conflict between NTFPs collectors and Orang-utan, since they will compete to get fruits from these paludiculture species. The government, together with local communities, should formulate relevant policies or regulations to avoid this conflict. The morphological character of *Shorea spp.*, *Aleurites moluccana*, *Nothaphoebe coriacea*, and *Gonystylus bancanus* can provide benefits as the shelter of Orangutan and windbreaks for forest protection. Moreover, NTFP collectors can generate income from nuts that produced by *Shorea spp.* (Illipe nuts) and *Aleurites moluccana* (candlenut). *Nothaphoebe coriacea* can be used as the shade tree before harvest. However, this species can only be harvested once due as the most used technique of harvesting incense bark of *Nothaphoebe coriacea* is by cutting down the trees (Tata and Susmianto, 2016). Moreover, the incense from *Gonystylus bancanus* will not be harvested for this scenario due to unsustainable harvesting (Pennacchio et al., 2010, Tata and Susmianto, 2016).

*Nitrogen fixation scenario*

In this nitrogen fixation scenario, we selected six potential paludiculture species; i.e. *Sindora velutina Baker*, *Derris trifoliata*, *Spatholobus ferrugineus*, *Uraria crinita*, *Ipomoea aquatica Forsk.*, and *Momordia charantia. Sindora velutina Baker*, *Derris trifoliata*, *Spatholobus ferrugineus*, *Uraria crinita* are legumes in the Fabaceae family. In this scenario, these nitrogen-fixation plants are combined with vegetable species i.e. *Ipomoea aquatica Forsk.* and *Momordia charantia.* The availability of nitrogen is requisite for optimal vegetable growth and yield; thus, the nitrogen fixation plants and vegetable have a mutual benefit (Susila et al., 2012). Local communities can consume these vegetables as food, or they can sell it for additional income. *Sindora velutina Baker* is used for making paints and varnishes. *Derris trifoliata* and *Spatholobus ferrugineus* are used for binding material. Moreover, local communities already used *Uraria crinita* as traditional medicine.

### 4.3. Result of Stakeholder Analysis

The influence and interest of each stakeholder towards agroforestry-based paludiculture is provided in the Venn-Diagram (Figure 2). The influence is defined as the power of the stakeholders to control what decisions are made and to facilitate the implementations. Furthermore, the interest is defined as the stakeholders' needs and interests that are likely to be affected by this project (Kumasi, 2008).

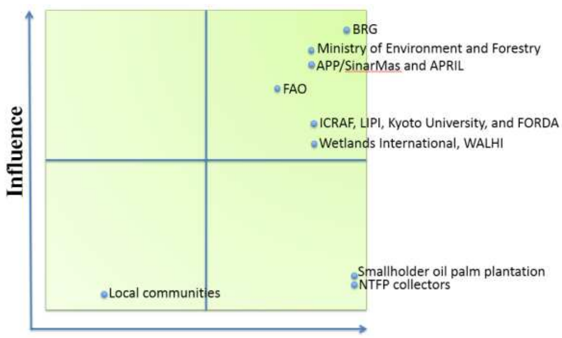


Figure 2 Venn-Diagram of stakeholders

The point of view on paludiculture from the stakeholders is described below:

***Private sector***

*APP (Asian Pulp & Paper)/SinarMas* is one of the largest pulp & paper and palm oil companies in Indonesia. This company has 600.000 hectare of drained pulp wood plantation on peatlands and deforested many more peatlands and can therefore be considered one of the biggest drivers of peatland degradation in Indonesia. Recently it however, retired 7000 hectares of pulp wood plantation of PSF restoration and the piloting with paludiculture species (Asia Pulp & Paper, 2015). This area only constitutes 2% of APPs total land that is managed with business as usual (Baffoni et al., 2017). It however shows there is a basis for paludiculture development as part of its best practices management practices on peatlands (Koalisi Anti Mafia Hutan et al., 2013). Moreover, this company vowed to rewet and restore 7,000 of the 600,000 ha of peat plantations it owns and to consult the local communities to help protect it (Butler, 2015).

*APRIL (Asian Pacific Resources International Limited)* is the second largest pulp and paper company in Indonesia. APRIL has widely promoted business as usual and influenced the Indonesian legislation to facilitate drainage based plantation development on peatland. It however was already aware of the limits to drainage from the Kampar Peninsula Science Based Management Support Project. As a result of the project however, APRIL has installed some buffer zones and planted *Melaleuca cajuputi Powell* and other PSF species in a very early stage (Hooijer, 2008, Hooijer et al., 2009). Currently they are broadening their piloting phase by including more than 50 species, including bamboo (IPEWG, 2017). APP and APRIL have about half of their plantations on peatlands and drainage-based management remains the business as usual. NGOs believe they should do more to avoid the disastrous consequences of their management, such as HCV development from all remaining PSFs, no new developments that require peatland drainage, the development of hydrological buffer zones, drainage-based plantations phase out, and the implementation of environmental and social safeguards (Silvius, 2015, Baffoni et al., 2017). Based on Government Regulation (PP) 71/2014, APP and APRIL are required to restore peatland that is drained more than 40 cm. As acacia and palm oil cannot grow with water levels at 40 cm, so APP and APRIL can plant paludiculture in their peatland area.

Private sectors have the permit to manage the peatland for economic purpose; thus they have high interest in keeping the peatland productive. On a mid to long term this can only be maintained using paludiculture. Although the private sectors don't have as much power as government, they still have quite high influence to implement paludiculture compared to other stakeholders.

***Government bodies***

*BRG (Peat Restoration Agency)* is a non-structural agency under the auspices of and reports to the president and responsible for restoring 2 million hectares of degraded peatland in Indonesia (Wardhana, 2016). BRG's goal for 2016-2020 is to rewet two million hectares of degraded peatland in seven priority areas. This stakeholder has the a very high influence as it is mandated to enforce peatland restoration.

*MoEF* (*Indonesian Ministry of Forestry and Environment)* recommends paludiculture for the restoration activities in peat protection zones (Prayitno and Munandar, 2016). Furthermore, MoEF adopted agroforestry for the regulation on Economic instruments for Environmental Protection and Management (CGIAR et al., 2015).

Government bodies are responsible to rehabilitate and to restore the degraded peatland. Thus, these stakeholders have highest influence and interest on paludiculture implementation.

***Civil societies***

*NTFPs collectors* prefer to restore the PSFs. They have local traditional knowledge of the surrounding forests and natural environments (such as: fruiting seasons and animal behaviour patterns), the level of dependency of NTFPs is high. Therefore, the NTFPs collectors will neither choose paludiculture plantations nor palm oil/acacia plantations (Sundari, 2005). However, with building capacity to manage paludiculture agroforestry they could be stakeholder which is interested in paludiculture.

*Local communities* can gain economic benefits from agroforestry-based paludiculture plantation; such as goods (food, fuel, construction material, handicrafts), income and employment (Ros-Tonen and Wiersum, 2003). Furthermore, these NTFPs from paludiculture are intended mainly for the welfare of local communities (Rijsoort, 2000). Local communities represent various people with different needs and preference, thus they have the lowest influence and interest.

*Smallholder palm oil plantations* may refuse this paludiculture concept. The economic benefits from oil palm plantations are crucial for smallholder farmers in remote areas that have limited source of income (Agustira et al., 2016, Bertazzo, 2016). Smallholder farmers expand their land by acquiring peatland areas for oil palm plantations to increase the income (Agustira et al., 2016). Another case in Bengkalis Regency, smallholder palm oil farmers converted their palm oil into pineapple due to economic reason (SPKS, 2017). However, pineapple plantations need water table depth around 75-90 cm, which is also unsustainable for peatland management (Arunin et al., 2009).

***NGOs and Research Institutes***

*WALHI (Wahana Lingkungan Hidup Indonesia)* is the biggest local environmental NGO in Indonesia that supports the environmental restoration and rehabilitation (WALHI, 2016). WALHI Riau, together with local communities, initiated the Sago Festival Riau event to promote sago products, to develop sago innovations, and to add extra value for sago products (Balitbang Riau, 2016).

*Wetlands International* is an international NGO with an office in Indonesia that supports paludiculture as an economic incentive to rewet degraded peatlands, which reduced environmental impacts and enhances livelihoods of local people (Wetlands International, 2017, Wetlands International, 2015).

*FAO (Food and Agriculture Organization of the United Nations)* is a specialised agency of the United Nations to improve the production and distribution of agricultural products. This UN agency has a significant role to support research and to identify paludiculture as sustainable peatland management (Fitri, 2016) and is doing so through their MICCA project (FAO, n.d.).

*ICRAF (World Agroforestry Centre)* is a research institute that focuses on agroforestry development. According to Widayati (2016), paludiculture is one of the peatland restoration and rehabilitation options to reduce forest fires and GHG emissions. ICRAF also suggests that the area with productive functions can be planted with agroforestry, paludiculture, or a combination of them.

*LIPI (Indonesian Institute of Science)* is a research institute that supports the peatland restoration and rehabilitation. LIPI has published many literature resources for PSF plants (LIPI, 2016).

*Kyoto University, research institute for humanity and nature, Japan* is a university and research institute that conduct integrated research in the field of global environmental studies. Kyoto University acknowledges that the paludiculture activities are suitable for the sustainable peatland management in tropical peatland. The paludiculture should be developed based on the local knowledge, local economy, and value-chain to the domestic and international markets (Kyoto University, 2016).

*FORDA (Research, Development and Innovation Agency)* is a research institute under the responsibility of the Indonesia Minister of Environment and Forestry. According to FORDA, paludiculture is a sustainable wetland management technique. Paludiculture can maintain the natural peatland condition, produce biomass, and preserve ecosystem services in peatland. FORDA also suggests that paludiculture should be included in environmental and forestry development strategic plan (Rizda, 2016).

NGOs and research institutes have high influences in the paludiculture implementation since they have the data and information about paludiculture. Their interests are also high, since they mainly focus on peatland restoration and rehabilitation.

## 4.4. Result of Multi-criteria Analysis (MCA)

***Performance criteria***

Six agroforestry criteria were adapted from Tengnäs (1994) and ecosystem services analysis (See Section 3.2 and 3.3). The first two criteria are ecological aspects. The next three criteria have to do with the economic aspects. The last criterion is about the nitrogen-fixation ability.

- Well-known species
- Food for animals
- Years to maturity
- Market price
- Market availability
- Nitrogen fixation

*Well-known species* is the primary criterion for selection of agroforestry in peatland to identify the preference by farmers. It also identifies whether the information about the paludiculture species is widely available or not.

*Food for animals* indicates the edibility of paludiculture species for animals, especially Orangutans.

*Years to maturity* indicates the length of time that the trees and crops can be harvested.

*Market price* indicates the revenue from trees or crops production in the market (Rupiah/ha/year).

*Market availability* is defined as the access to markets for the agroforestry productions.

*Nitrogen fixation* indicates that the paludiculture species have symbiotic relationships with nitrogen-fixing bacteria.

***Ranking, Weighting, and Scoring***

The ranking of the various criteria was done based on the literature review. The detailed ranking results are shown in Annex 3. The weighting procedures by the stakeholders (see Section 4.3) were done based on the literature to identify the importance of each criterion to the three scenarios. However, not all stakeholders had equal weight in the decision-making. Based on the Venn-Diagram (Figure 2), Governments have the highest influence and power in the final decision-making in among all stakeholders. Therefore, Governments have the highest percentage weighting with 50%, followed by private sectors (APP/SinarMas and APRIL) with total of 25%, NGOs and Research Institutes (WALHI, Wetlands International, FAO, ICRAF, LIPI, Kyoto University, and FORDA) with total of 15%, and civil societies (local communities, smallholder oil palm plantations, and NTFP collectors) with total of 10%. The detailed weighting results are presented in Annex 4. Table 4 shows the final score from ranking and weighting calculation.

Table 4. Final score of three agroforestry-based paludiculture scenarios

| Criteria | Economic focus | Biodiversity conservation focus | Nitrogen fixation focus |
|---|---|---|---|
| Well-known species | 16.06 | 16.06 | 5.35 |
| Food for animals | 6.44 | 5.15 | 2.58 |
| Years to maturity | 8.63 | 5.76 | 4.56 |
| Market price | 18.58 | 14.96 | 5.90 |
| Market availability | 21.91 | 21.91 | 10.96 |
| Nitrogen fixation | 0 | 0 | 6.21 |
| **Total scores** | **71.62** | **63.48** | **35.55** |

Based on Table 4, economic focus scenario generated the highest score with 71.62, followed by Biodiversity conservation focus scenario with 63.48 and Nitrogen fixation focus scenario with 35.55. It means that when ecological, economic, and nitrogen fixation criteria are taken into account, the economic focus can be identified as favourable agroforestry-based paludiculture compared to Biodiversity protection focus and Nitrogen fixation scenarios. The score between the economic focus and the biodiversity conservation focus are almost comparable so that biodiversity conservation focus can be an alternative to this agroforestry-based paludiculture.

# 5. DISCUSSION

## 5.1. Uncertainties and Limitations

There are some limitations in this study that have to be recognised as they could have triggered possible biases of the results. Regarding the compositions of agroforestry, for some paludiculture data is unknown. We assumed that these agroforestry-based paludiculture compositions could rewet and restore the degraded peatland because they consist of paludiculture species that have the ability to do so. However, we suggest further research to improve this missing data.

The selection of paludiculture species and stakeholders is based on the ecological and economic criteria by using data and information from the existing literature reviews. The selection of paludiculture species are available in many kinds of literature; thus, the data and information are still accurate. The selection of stakeholders is conducted by reviewing literature and consulting with some stakeholders; hence the data and information are still reliable. The MCA was attained subjectively since this analysis is based on the authors' knowledge and mindset. For example, the choice of criteria, scoring, and weighting in MCA strongly influences the final outcomes. However, the authors already addressed the criteria, scoring and weighting neutrally.

Besides, this study only analyses 16 potential paludiculture species and includes the 14 key stakeholders in the Indonesia peatland due to time and financial limitations.

## 5.2. Comparison between three scenarios based on stakeholders' preference

Since this research only analysed provisioning services that are generated from the paludiculture, the economic benefits are calculated from the market price of the products from the paludiculture species. Economic focus scenario can support the local business by implementing agroforestry-based paludiculture with high economic products. It also improves the market availability of paludiculture species for local business since each paludiculture species already had high demand from foreign countries. Private sectors tend to prefer the paludiculture species within this scenario for agroforestry composition.

Biodiversity conservation focus is also a potential alternative scenario for sustainable peatland management in Indonesia. Local communities can gain economic benefits from the fruits or other NTFPs of paludiculture species. However, due to the conflict between human and Orangutans, this scenario will lose 27.4% of total income from *Garcinia mangostana* and *Nephelium lappaceum*. Thus, this scenario lacks economic activities in peatland. This scenario can also gain benefit from carbon sequestration by collaborating with REDD project (Mongabay, 2013). Moreover, this scenario also protects orang-utan as umbrella species that can be used for tourism attraction (Indonesia Tourism, n.d.). The Governments, Research Institutes and NGOs tend to prefer the paludiculture within this scenario for agroforestry composition.

Nitrogen fixation scenario has the lowest score in Multi-Criteria Analysis. This scenario provides food (vegetables) for local communities. The nitrogen fixation ability of paludiculture species is needed in the peatland, mainly for the plant growth (Flynn and Idowu, 2015). However, the market availability of paludiculture species in this scenario is yet unknown. These paludiculture species focuses on the function as nitrogen fixation, although they are not sellable products in the market. Thus, the economic benefit from this scenario is lower than two other scenarios. Civil societies tend to prefer the paludiculture within this scenario for agroforestry composition.

## 5.3. Agroforestry-based paludiculture in supporting gender equality in Indonesia peatland

Agroforestry-based paludiculture can support the sustainable development in peatland by promoting the gender equality (Murdiyarso et al., 2005). According to Sapiie (2017), Indonesia is still struggling to close the difference in the roles of women and men. The role of women in peatland restoration using agroforestry-based paludiculture can increase the local communities' welfare.

One of the government programs for local farmers' welfare is Female Farmers Group (KWT). The objective of KWT is to improve the capability of the farmers and their families as the subject of agricultural development. KWT also can be implemented in the agroforestry-based paludiculture in Indonesia peatlands (Oemar, 2017). In South Kalimantan study case (Perspektif Baru, 2017), women have an important role in restoring peatland. These women went to the peatland to cultivate *Eleocharis dulcis*. Moreover, they are processing *Eleocharis dulcis* into mats or bags. These women can increase the family income while helping to protect the peatlands. Another case is a female group in Mantangai Hulu, Kapuas. They also participate in peatland restoration. They cultivated *Metroxylon sagu Rottb.* from the peatland. (Oemar, 2016).

Therefore, women have the abilities to take a role in peatland restoration, especially in nitrogen fixation scenario. In this scenario, women and housewives can work in the field to cultivate nitrogen-fixation paludiculture species (such as *Ipomoea aquatica Forsk.* and *Momordia charantia.)*.

## 6. CONCLUSION

This study identified at least 16 potential paludiculture species in Indonesian peatland in term of ecological and economic aspects. These paludiculture species produce useful NTFPs; such as fruit, vegetable, starch (non-seed), latex, rattan, essential oil, incense, incense bark, oil-bearing nut, edible nut, resin, binding material/cordage, and medicine. There are three potential agroforestry-based paludiculture compositions in peatland, namely economic focus scenario, biodiversity conservation focus scenario, and nitrogen fixation scenario. Private sectors and Governments are more aligned with economic focus scenario, Research Institutes and NGOs are more aligned with biodiversity conservation focus scenario, and Local communities are more aligned with the nitrogen fixation scenario. Finally, this study revealed 14 main stakeholders that were analysed in term of their preference in agroforestry-based paludiculture compositions. In Multi-Criteria Analysis, these stakeholders tend to prefer the economic focus scenario, followed by biodiversity conservation focus scenario as an alternative.

## 7. RECOMMENDATION

There are some available data and information about paludiculture species (Tata and Susmianto, 2016, Suwarno, 2017, Giesen, n.d., Giesen and van der Meer, 2009, Giesen, 2015a, Giesen, 2015b, Joosten et al., 2012, Widayati, 2016, Victoria et al., 2012). Moreover, the economic focus and biodiversity conservation focus scenarios are recommended as agroforestry-based paludiculture compositions in Indonesian peatlands. Since the agroforestry scenarios are based on literature review, the impact of these scenarios remains unknown. Thus, more field experiments are needed to investigate the possibility and the probability of agroforestry-based paludiculture plantation in Indonesia peatland, such as the impact of agroforestry composition to the peatland, the risk of forest fires, soil subsidence, and flooding, etc.).

Knowledge about paludiculture species that is available with communities need to be consolidated, exchanged and lessons learned drawn. There is still a knowledge gap about gender equality in local communities about agroforestry-based paludiculture plantation. Thus, social studies are needed to investigate further relationship between local communities and agroforestry-based paludiculture. Since these paludiculture species have high potential economic value, it is recommended to develop these species in the village forests to increase local communities' income.

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## APPENDICES

Annex 1. Identification results of 16 paludiculture species in term of economic aspect

| Species | Common name | Product | Market price (Rupiah/ha /year) | Market availability | First harvesting | Harvest cycle |
|---|---|---|---|---|---|---|
| *Garcinia mangostana L.* | Manggis (Mangosteen) | Fruit | 60,000,000 | High demand on export (BPS, 2016a) | 6 years (Roostika et al., 2016) | Each year (Roostika et al., 2016) |
| *Nephelium lappaceum L.* | Rambutan | Fruit | 25,173,610 | One of the most fruit production in 2014 (Taufik, 2015) | 8-10 years (Hasani, 2017) | Each year (Hasani, 2017) |
| *Ipomoea aquatica Forsk. (I. reptans)* | Kangkong | Vegetable | 10,261,431 | Locally consumed (Usaha Pertanian, 2014) | 28 days (Sophea and Preston, 2001) | Once (Sophea and Preston, 2001) |
| *Momordia charantia L.* | Paria (Bitter melon/ bitter gourd) | Vegetable | 15,652,000 | Locally consumed (Soetiarso, 2013) | 90 days (Palada and Chang, 2003) | Once (Palada and Chang, 2003) |
| *Metroxylon sagu Rottb.* | Sagu (Sago) | Starch (non-seed) | 37,547,548 | Locally consumed and export (Jong and Widjono, 2015) | 6 years (Suwarno, 2017) | Each year (Suwarno, 2017) |
| *Dyera costulata (Miq.) Hook.f.* | Jelutung | Latex | 8,926,608 | Export to Japan (Harun, 2011) | 7 years (Suwarno, 2017) | Each year (Suwarno, 2017) |
| *Calamus sp.* | Rotan (Rattan) | Rattan | 7,000,000 | Furniture/meubel (Suwarno, 2017) | 3 years (Suwarno, 2017) | Each harvest (Suwarno, 2017) |
| *Melaleuca cajuputi Powell* | Gelam | Essential oil | 3,890,900 | Ointments, balms (e.g. tiger balm), medicines and aromatherapy (Giesen, 2015b) | 3-4 years (Giesen, 2015b) | Each year (Giesen, 2015b) |
| *Nothaphoebe coriacea (Kosterm.) Kosterm. (Alseodaphne)* | Gemor | Incense bark | 4,166,667 | High economic wood/conservation function (Tata and Susmianto, 2016) | 40 years (Istomo et al., 2010) | Once (Istomo et al., 2010) |
| *Gonystylus bancanus (Miq.) Kurz.* | Ramin | Incense | 1,665,577 | High economic wood/conservation function (Tata and Susmianto, 2016) | 40 years (Istomo et al., 2010) | Once (Istomo et al., 2010) |
| *Shorea spp.* | Tengkawang | Oil bearing illipe nuts | 2,812,500 | Indonesia as the biggest exporter of illipe nuts (TECA, 2015a) | 8 years (Heri, 2013) | 3-5 years (Heri, 2013) |
| *Aleurites moluccana (L.) Willd.* | Kemiri (candlenut) | Edible nut | 4,737,070 | One of the contributors in Indonesian smallholder plantation (BPS, 2017) | 5-6 years (Herman et al., 2013) | Each year (Herman et al., 2013) |
| *Sindora velutina Baker* | sepetir beludu/ sindur | Resin | - | - | - | - |
| *Derris trifoliata (D. heterophylla)* | Tuwa areuy | Binding material/cordage | - | - | - | - |
| *Spatholobus ferrugineus* | Areuy carulang | Binding material/cordage | - | - | - | - |
| *Uraria crinita* | Ekor kucing | Poisons | - | - | - | - |

Annex 2. Identification results of 16 paludiculture species in term of ecological aspect

| Species | Common name | WTD (cm) | Soil PH | Peat Depth | Food for animals | Nitrogen content |
|---|---|---|---|---|---|---|
| *Garcinia mangostana L.* | Manggis (Mangosteen) | 30-70 (Wosten et al., 2008) | 5-7.0 (Mardiana and PS, 2011) | Shallow and medium (50-200cm) (Nasrul, 2010) | Yes (WWF, 2014) | No |
| *Nephelium lappaceum L.* | Rambutan | 30-70 (Wosten et al., 2008) | 4-6.5 (Sunarjono, 2006) | Shallow and medium (20-230cm) (Limin, 2006) | Yes (Nawangsari et al., 2016) | No |
| *Ipomoea aquatica Forsk. (I. reptans)* | Kangkong | 30-60 (Chotimah, 2002) | - | Shallow and medium (50-200cm) (Nasrul, 2010) | Yes (luff, 2013) | No |
| *Momordia charantia L.* | Bitter melon | 30-60 (Chotimah, 2002) | 6-6.7 (Palada and Chang, 2003) | Shallow and medium (50-200cm) (Nasrul, 2010) | No | No |
| *Metroxylon sagu Rottb.* | Sagu (Sago) | 20-40 (Ambak, 2000) | 4-5.0 (Biancalani and Avagyan, 2014) | Shallow, medium, and deep (0-300cm) (TECA, 2015b) | No | No |
| *Dyera costulata (Miq.) Hook.f.* | Jelutung | 0-50 (Jaenicke et al., 2010) | 3-4.0 (Giesen and van der Meer, 2009) | Medium and deep (100-300cm) (Jaenicke et al., 2010) | No | No |
| *Calamus sp.* | Rotan (Rattan) | - | 4.04-5.14 (Pantanella, 2005) | - | Yes, with human help (SOCP, 2013) | No |
| *Melaleuca cajuputi Powell* | Gelam | - | 3.1-3.9 (Komar et al., 2008) | Medium and deep (<3m) (Tata and Susmianto, 2016) | No | No |
| *Nothaphoebe coriacea (Kosterm.) Kosterm. (Alseodaphne)* | Gemor | - | 3-4.0 (Adinugroho et al., 2011) | Shallow, medium, and deep (Tata and Susmianto, 2016) | No | No |
| *Gonystylus bancanus (Miq.) Kurz.* | Ramin | 0-50 (Jaenicke et al., 2010) | 4-5.1 (Komar et al., 2008) | Shallow and medium (30-180cm) (Limin, 2006) | No | No |
| *Shorea spp.* | Tengkawang | 0-50 (TECA, 2015a) | 4.5-5.5 (Hidayati, 2010) | Shallow, medium, and deep (30-300cm) (TECA, 2015a) | No | No |
| *Aleurites moluccana (L.) Willd.* | Kemiri (candlenut) | - | 5-8.0 (Krisnawati et al., 2011) | - | | No |
| *Sindora velutina Baker* | sepetir beludu/ sindur | - | 2.7-4.0 (Riswan, 2014) | 5-10cm (FAO, 1984) | No | Nitrogen fixation (Ghazoul et al., 1996) |
| *Derris trifoliata (D. heterophylla)* | Tuwa areuy | - | 4.5-6 (Rabiati, 2016) | - | No | Nitrogen fixation (Kuykendall et al., 2003) |
| *Spatholobus ferrugineus* | Areuy carulang | - | - | - | No | Nitrogen fixation (Fujita et al., 1992) |
| *Uraria crinita* | Ekor kucing | - | - | - | No | Nitrogen fixation (Nzoue et al., 2006) |

Annex 3. Ranking result of recommended scenarios

| Criteria | Agroforestry composition | | |
|---|---|---|---|
| | Economic focus | Biodiversity conservation focus | Nitrogen fixation |
| **Ecology** | | | |
| Well-known species | 100 | 100 | 33.33 |
| Food for animals | 41.67 | 33.33 | 16.67 |
| **Economic** | | | |
| Harvesting year | 60 | 40 | 31.67 |
| Market price (rupiah/ha/year) | 81.33 | 65.50 | 25.83 |
| Market availability | 100 | 100 | 50 |
| **Nitrogen Fixation** | 0 | 0 | 66.67 |
| Total | **383** | **338.83** | **224.17** |

Annex 4. Weighting result of each stakeholder's preference

| Criteria | Stakeholders | | | | | | | | | | | | | | Combined weight (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Private sectors | | Government | | Civil Society | | | Research Institutes and NGOs | | | | | | | |
| | APP | APRIL | BRG | MoEF | NTFP Collectors | Smallholder palm oil plantation | Local communities | WALHI | Wetlands International | PBB-FAO | ICRAF | LIPI | Kyoto University | FORDA | |
| **Ecology** | | | | | | | | | | | | | | | |
| Well-known species | 2.50 | 1.25 | 5 | 3.75 | 0.17 | 0.17 | 0.33 | 0.43 | 0.43 | 0.21 | 0.43 | 0.54 | 0.32 | 0.54 | 16.70 |
| Food for animals | 1.25 | 1.25 | 5 | 3.75 | 0.50 | 0.33 | 0.17 | 0.43 | 0.43 | 0.64 | 0.32 | 0.64 | 0.32 | 0.43 | 16.30 |
| **Economic** | | | | | | | | | | | | | | | |
| Harvesting year | 2.50 | 2.50 | 2.5 | 3.75 | 0.33 | 0.17 | 0.50 | 0.32 | 0.32 | 0.32 | 0.32 | 0.21 | 0.32 | 0.32 | 14.70 |
| Market price (rupiah/ha/year) | 3.75 | 3.75 | 5 | 6.25 | 0.67 | 0.83 | 0.67 | 0.32 | 0.32 | 0.43 | 0.21 | 0.11 | 0.32 | 0.21 | 23.00 |
| Market availability | 2.50 | 3.75 | 5 | 6.25 | 0.67 | 0.83 | 0.67 | 0.43 | 0.43 | 0.54 | 0.21 | 0.11 | 0.32 | 0.21 | 21.90 |
| **Nitrogen Fixation** | 0 | 0 | 2.5 | 1.25 | 1 | 1 | 1 | 0.21 | 0.21 | 0 | 0.64 | 0.54 | 0.54 | 0.43 | 7.30 |
| Total | 12.50 | 12.50 | 25 | 25 | 3.33 | 3.33 | 3.33 | 2.14 | 2.14 | 2.14 | 2.14 | 2.14 | 2.14 | 2.14 | 100 |