Development of agroforestry oil palm for peatland restoration in Jambi Province: establishing process and initial results

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Abstract. Rapid degradation of peatland forest in Indonesia is caused by conversion into plantation forest and agriculture land, including oil palm plantation by farmers. Restoration of peatland is then needed with involvement of local farmers as main stakeholder. This paper presents establishment process and initial result from an action research on peatland restoration using biodiversity enrichment experiment in existing oil palm smallholder plantation to develop oil palm agroforestry. The experiment was established in Sinar Wajo Village, Tanjung Jabung Timur Regency, Jambi Province in which 30 plots in sizes of 25m², 100 m², and 400 m² placed systematically over about 21 ha oil palm plantation belong to a group of farmers. There were 1,180 trees of 6 species, i.e. blangeran (Shorea blangeran), pinang (Areca pinanga), petai (Parkia speciosa), durian (Durio zibethinus), jengkol (Archidendron pauciflorum), and kopi liberika (Coffea liberica) with 0, 3, and 6 diversity levels, created tree island on the sea of oil palms. Approach to local leaders was very important for the initiation of the action research. Focus group discussion with farmer group, provision of seedlings and labour wages were conducted to ensure farmer willingness of participation. Capacity building, such as training on tree cultivation, bio-fertilizer production and study tour was conducted as incentive for farmers. The initial result of plant growth measurement from experiment plots showed 21 months after planting many planted trees grew well. Blangeran as native species of peatland forest showed the best growth performance. Pinang, Kopi Liberika and Durian were also showed relatively good growth performance. Only Petai and Jengkol showed less growth performance. High farmer participation on the establishment of oil palm agroforestry as peatland restoration model was mostly driven by provision of incentives. Oil palm agroforestry is a promising model for restoration of already planted by oil palm peatland area, and involving farmers is important factor for the success of peatland restoration through appropriate social approaches.

Keywords: biodiversity enrichment, oil palm, social approach, restoration model, peatland

1. Introduction
Oil palm has the highest productivity compare to other oil producing crops [1] and highest demand due to various application and availability of the product [2][3]. Those comparative benefits of oil palm become the driver factors of the increasing of land conversion into oil palm plantations in the last two decades in Indonesia that then oil palm contributed significantly to the increasing of community economic [4] [5] and the Gross Regional Domestic Product in Indonesia [6].
Conversion of tropical forests including peatland forest into monoculture oil palm plantation is considered as the major driver of dramatic losses of biodiversity and ecosystem functions [7], high carbon emission [8], and caused transboundary haze pollution contained various poisonous gasses [9] from slash and burn clearing practices. Trade-off between economic gain and ecological functions that occurred on the practice of agriculture and forest conversion has been widely discussed in scientific articles [10][11][12]. But oil palm growers considered that cultivation of oil palm in monoculture plantation is the best way to maximize yield and benefit, although the gap in yield still occurred due to various factors affected potential yield, water-nutrient limited yield and actual yield [13], so that monoculture oil palm plantation still widely practice in Asia, Africa and South America. Although that [14] reported that in West Africa and Brazil, farmers traditionally practiced extensive oil palm based agroforestry. Agroforestry is known as land use system that provides solution for land management problems so that could increase biodiversity [15], reduce carbon emission [16], reduce erosion and improve soil fertility [17], and profitability toward total farm income [18].

In Indonesia few farmers intercropped oil palm with short period of crops such as maize and ground nut but only in the young stage of oil palms to provide income before oil palm harvesting but it has almost no ecological benefit. There are few experiments in the previous time on planting woody trees with oil palm, but they have never been practiced in large scale. Current experiment on oil palm intercropping with woody perennial called Biodiversity Enrichment Experiment (BEE) has shown promising results toward balancing economic and ecological functions. The BEE is established since 2013 at an oil palm plantation belong to a private company that located on mineral soil area in Batanghari Regency, Jambi Province Indonesia [19] [20]. Could similar biodiversity enrichment be applied to restore peatland forest that has been converted into oil palm plantation by smallholder farmers? An action research on peatland restoration has been conducted in 2017 using biodiversity enrichment experiment in existing oil palm smallholder plantation to develop oil palm agroforestry supported by Badan Restorasi Gambut, a national institution on peatland restoration. According to [21], main principles of peatland restoration are rewetting, reforest/revegetation, ensuring community support and stimulating community development. So that the objective of development agroforestry oil palm was not only to restore peatland using revegetation principle but also to stimulate community support and development. This paper presents the process of agroforestry establishment and the initial results from first two years monitoring.

2. Methodology

2.1. Location

The restoration project was established in Sinar Wajo Village, East Tanjung Jabung Regency Jambi Province. The experiment location is at oil palm plantation belong to smallholder farmers who live at Sungai Nek hamlet which is located inside the village forest area.

2.2. Project Implementation

To initiate the oil palm agroforestry experiment in Sinar Wajo Village a social approach [22] was used to develop farmer interest and participation as the owner of the oil palm plantations. The oil palm agroforestry experiment was a modified experiment from the BEE at Batanghari Regency [19]. Due to the small area of oil palm plantation (21 ha), only 30 plots (including control plots) were established in sizes of 25m$^2$, 100m$^2$, and 400m$^2$ that placed systematically at distance about 50 m to each other. The plots formed tree islands inside of the sea of oil palms. There were 1,180 trees of 6 species, i.e. Blangeran (Shorea belangeran), Pinang (Areca pinanga), Petai (Parkia speciosa), Durian (Durio zibethinus), Jengkol (Archidendron pauciflorum), Kopi liberika (Coffea liberica) with 0, 1, 3, and 6 diversity levels. Zero level of diversity means no trees planted in the plots and served as control plots. Trees were planted in the plots with 2m x 2m grid. Lay out of the plots is shown in Figure 1.
2.3. Experiment monitoring
The basic site condition (depth of peatland, soil pH, and initial vegetation) was studied before experiment plots were established. After that, the planted tree growth (height, diameter and mortality) was monitored.

3. Result and Discussion

3.1. Development of Community Participation
Peatland restoration should involve community participation because most of the peatland area has been converted into agriculture land by community. In Sinar Wajo Village, more than 50% of 5,088 ha peatland forest, its status was village forest, has been converted into agriculture land and planted mostly by oil palms. According to [23] that local people is essential to be involved in the restoration process and derive financial and social benefits from it. So, the first step of the research project implementation was to introduce the agroforestry oil palm system to the people of Sinar Wajo Village. The first approach was conducted to the local leaders including village head and village office staffs, head of forest village management and farmer leaders through a village meeting using focus group discussion method which is often used in a participatory research [24], with the aim in this research was to get permit and approval from the village government and to select the suitable site for the experiment.

Sungai Nek hamlet was then selected as the site for the agroforestry oil palm experiment due to the accessibility, the location which is inside the village forest, and the people who are mostly dominated by Java ethnic as the third largest population of Sinar Wajo Village after Bugis and Banjar ethnics. The Java ethnic was regarded as easier to collaborate due to their nature of culture and their solidarity affection since the researchers came from Java Island that described by [25] as high collectivism-low individualism suggested that there are strong needs of the Javanese to be close to one another and to be very conscious of any elements which may reduce the quality of their togetherness.

There were 10 farmers willing to participate in the research and provided about 21 ha of oil palm plantation as experiment site. Their willingness of farmer participation was developed through a series
of focused group discussions and enhanced by the provision of tree planting materials and employment as labour for experiment plot establishment. Participation of farmers in oil palm agroforestry experiment was also enhanced by conducting a study tour to the research site of the BEE in Batanghari Regency, training on bio-composting and briquettes production as incentives for them. This result is in line with research by [26] that information campaigns and structural interventions can motivate tree planting among smallholder oil palm farmers.

Prior to the research, attempts on peatland restorations have been done in Sinar Wajo Village by government, such as planted jelutung trees (*Dyera pholiphylla* (Miq) Steenis) in the farms area. Jelutung is a native peatland species that could produce latex [27]. Although jelutung trees could grow well, but according to the farmers many jelutung trees died due to wild boars that were plenty in the area, so that only few jelutung trees remain at the farms in Sinar Wajo Village. Because of that on the tree species selection for the experiment, farmers strongly opposed to planting jelutung, not only due to the wild boars attack but also no market for jelutung latex. Result of focus group discussion with the farmers, 6 species, i.e. Blangeran (*Shorea belangeran*), Pinang (*Areca pinanga*), Petai (*Parkia speciosa*), Durian (*Durio zibethinus*), Jengkol (*Archidendron pauciflorum*), Kopi liberika (*Coffea liberica*) were agreed by them to be planted in the experiment (Table 1).

### Table 1. Number of planted tree species

| No | Name          | Scientific Name                  | Number of planted trees |
|----|---------------|----------------------------------|-------------------------|
| 1  | Durian        | *Durio zibethinus*               | 179                     |
| 2  | Jengkol       | *Archidendron pauciflorum*       | 212                     |
| 3  | Kopi liberika | *Coffea liberica*                | 185                     |
| 4  | Pinang merah  | *Areca pinanga*                  | 135                     |
| 5  | Petai         | *Parkia speciosa*                | 273                     |
| 6  | Belangeran    | *Shorea belangeran*              | 196                     |
|    | Total         |                                  | 1180                    |

Pinang was commonly planted by farmers as one of important income sources and few farmers already planted liberika coffee which is very adaptive to peatland. Fruits of Petai, Durian and Jengkol have high demand but almost no farmers planted them in Sinar Wajo Village, so that supply of those fruit always come from outside the village once a week during weekly market. Belangeran is a woody tree species that is native to peatland and selected by farmers as the substitute of jelutung. The selection of tree species planted in the experiment plots has considered the market value and demand, oil palm plantation condition and diversification of plant composition that was in line with [28] who concluded their research that transformation of the monoculture system with low sustainability towards more sustainable farming practices of agroforestry systems can actually be achieved through five considerations identified as (i) crop component (ii) maturity of oil palm (iii) market values and demand (iv) belowground and aboveground interaction, and (v) diversification of plant composition and arrangement.

### 3.2. Plot establishment

Study on the biophysical condition of the experiment site showed that (1) the site was dominated by oil palms which planted mostly in 2012 until 2015, but with the condition of relatively open as the effect of land fire in 2015 and the poor growth due to low maintenance; (2) only few number of other trees was present in the site, i.e. pinang and jelutung; (3) understory vegetation was dominated by pioneer grasses and ferns; (4) the peat soil in the site could be classified as *sapric*, means the peat was already mature shown from the dark brown color of the peat soil and no fiber was remain on the palm after the peat soil was squeezed by hand [29]; (5) the depth of peatland is varied from 2 m until 2.5 m with water table about 30 cm until 67 cm measured on October 2017; and (4) the peat soil was very acidic with pH 4.5.
Plot establishment was started with mapping of plots or plot lay out (see Figure 1). Using the plot lay out as guidance; a ground trothing was conducted to find out the middle coordinate of plots using GPS. After the middle coordinate of the plot was decided then the boarders of the plot were marked by poles made from wood. The plots were then fenced using woody poles and metal wire to protect the plated tree seedlings from wild boar attack. Planting tree seedlings was conducted after the plots were fenced. Because the peat soil of sapric was also classified as oligotropic which has low soil fertility [29], so that one week before tree planting liming was conducted around the planting holes using dolomite to increase soil pH and also compost from manure and chemical fertilizer (NPK) were applied to increase soil fertility.

Establishment of experimental plots was conducted in collaboration with farmers who are also the owner of the oil palm plantations. They were paid to work on the establishing process according to the agreed wage that is lower than local wage. In the same time, they were also given education on how to use GPS tool, marked the plots and measure the tree dimension as a transfer knowledge and skill from researcher to the farmers. Unfortunately, about two months after establishment, many plots were attacked by wild boars caused the damage of planted tree seedlings and plot fences. So, that the tree seedlings had to be replanted and the fences were repaired. Several plots were then relocated to avoid wild boar attack. The number of plots was reduced due to limited funding. But in the second year project -2018- new experiment plots were established to complete the planned design.

3.3. Tree Growth Performance
The tree seedlings for the experiment came from various sources. Seedlings of Blangeran, Durian, Jengkol and Petai were come from Forestry Research Centre in Palembang, South Sumatera Province. While seedlings of Pinang and Kopi liberika were bought from local farmers who cultivated those plant species in their farm lands. Because the tree seedlings came from various sources, so they varied in diameter (5 to 9 mm) and height (30 to 60 cm).

![Figure 2. Average tree diameters and average tree height at 5, 12 and 21 months after planting](image)

Result from 3 times monitoring (5, 12 and 21 months after planting) of plant growth at experiment plots (Figure 2) showed that Pinang has the highest diameter growth followed by Blangeran. But in term of height, Blangeran has the highest growth performance followed by Pinang. Jengkol has the lowest growth performance both in diameter and height.
Figure 3. Survival rates of planted tree species at 5, 12 and 21 months after planting

Figure 3 showed that in the first 5 months after planting, the six tree species have very good survival rate (>90%) except for Petai (88%). One year after planting, showed the decreasing of survival rate of all the tree species. Although that Blangeran and Kopi liberika still showed good survival rate (>80%), but Durian and Jengkol have the lowest survival rate. At the age of almost 2 years (21 months after planting) Blangeran has the highest survival rate (76%), followed by Pinang (71%). Jengkol is the only tree species that showed the very low survival rate compare to other tree species. On the other hand, Durian which showed the same survival rate with Jengkol at one year after planting has moderate survival rate (40%) the same as Kopi liberika.

Variation on growth performance and survival rate of planted tree species in the experiment plots most likely due to the adaptation characteristic of each tree species into the peatland condition that naturally flooded during the peak of rainy season. *Shorea belangeran* is a native species of peatland and its distribution is confined almost exclusively to peatland habitat and included in IUCN red list of globally endangered species [23]. So, Blangeran showed the best growth performance. Jengkol has the worst growth performance besides due to the poor condition of seedlings (in average smallest dimeter and height) at the beginning of planting, but also poor adaptation to peatland condition because Jengkol is not a native peatland species. In the BEE at Batanghari Regency, Jengkol was one of the best growth performance species [20] showed that Jengkol more adaptive to mineral soil than peat soil. Petai which is not a peatland native species showed relatively good growth performance. Hopefully Petai could adapt to peatland soil, so that could become source of income for farmers and improve peatland soil fertility because Petai as one of Fabaceae family known to have ability on nitrogen fixation. Pinang and Kopi liberika have been cultivated by farmers, although in the relatively shallow peatland, showed that in the more depth peat soil could still grow relatively well. Durian trees mostly cultivated at mineral soil area has apparently wide range of growth distribution. Result of vegetation survey of remaining peatland forest at Sinar Wajo Village by [30] showed that Durian was among 10 tree species found in the peatland forest of Sinar Wajo Village.

4. Conclusion
Oil palm agroforestry is a promising model for restoration of already planted by oil palm peatland. Selection of tree species or crops to be integrated with oil palm should consider the adaptability of tree species into peatland soil condition. Blangeran, Pinang and Kopi liberika showed initial good growth performance that could be promising for the future development of agroforestry oil palm at peatland area. Market value of tree species is one of factors that could interest farmers to plant trees integrated
with oil palm. Involving farmers is important factor for the success of peatland restoration through appropriate social approaches.

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