The suitability of forest tree species for enrichment planting at PT Semitau Region, West Kalimantan

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Abstract. Forest tree enrichment can improve biodiversity and ecosystem functions. Tree enrichment planting in the riverside rehabilitation area of palm oil plantation needs to be monitored to prevent the risk of erosion and sedimentation. However, regular monitoring of enrichment planting is not yet optimally carried out including the benefits and identified suitable species through field observations. This study was aimed to determine the three most suitable tree species to be recommended for enrichment planting in the riverside rehabilitation areas at PT Semitau Region oil palm plantation. Samples were determined through a combination of linear systematic sampling methods. The measured variables included the survival percentage, health, diameter, height, light intensity, and soil analysis. The results showed that the three species had the best adaptability, namely kawi (Shorea balangeran), pulai (Alstonia spp.), and ubah (Syzygium darifolium) with 21%, 15%, and 10% dominance frequency, respectively. Total dominance frequency of 45% for all three species are expected to be useful information for increasing successfully riverside rehabilitation area of oil palm plantation.

1. Introduction

Nowadays, oil palm has the most rapid growth in the Southeast Asia region [1]. Overall oil palm plantation areas in 2017 were estimated at approximately 18.7 Mio ha [2]. The expansion of oil palm has resulted in significant impact on biodiversity and ecosystem functions. Therefore, the policy rules in the form of sustainable certification have been created to reduce the environmental impact caused by palm oil, such as the Roundtable on Sustainable Palm Oil (RSPO), Indonesian Sustainable Palm Oil (ISPO), and Malaysian Sustainable Palm Oil (MSPO) [3]. The regulation guidelines relate to soil fertility and erosion, water management and riparian zones, integrated pest management, and protected areas of high conservation value [4]. The benefit of riparian zones on the environment is about maintaining water quality and hydrological patterns, protecting biodiversity, and increasing the potential for carbon storage in agricultural landscapes [5]. Management of riparian zones in oil palm plantations is carried out through the rehabilitation program with a distance of 50 m to the left and right from the buffer area. However, the literature discussed riparian zone rehabilitation strategies in oil palm plantations remains limited [3]. PT Semitau Region is one of the
palm oil plantation companies that have implemented a rehabilitation strategy through enrichment planting on its riversides. Enrichment planting is one way to carry out a rehabilitation program through the insertion of new plants in the gap planting between existing plants [6]. The condition of the land prior to the implementation of PT Semitau Region's operational activities were rubber plantations, former shifting cultivation of vacant land and shrubs, peat, and secondary forests of former timber companies.

PT Semitau Region oil palm plantation permit area was carried out in 2008 while [7] the planting rehabilitation area was begun in 2016. PT SR area located near the Kapuas Hulu river, whose flow forms a dendritic pattern and characterized by spreading flow. Overall, the indigenous tribe who inhabit the village area around the plantation area is Dayak Kantu with 90% composition [8]. The enrichment strategy that undertaken by PT Semitau Region was to insert forest species seedling with 4 m spacing from the main oil palm. However, the rehabilitation efforts did not completely well-run, many things that hampered success including internal and external factors. Internal factors include the suitability of plant species, while external factors include outside circumstances such as soil conditions, nutrient availability, competition between plants, and the presence of pests and diseases [9].

Monitoring the success of a rehabilitation project is very important to evaluate the efforts over the last four years. The scope of the study is adjusting the suitable forest tree species as enrichment plants. The result of the research is appropriate forest tree species information in order to minimize company losses due to rehabilitation failure. This study was aimed to determine the three most suitable forest species to be recommended as enrichment plants in the riverside rehabilitation area of PT Semitau Region oil palm plantation. Based on the last four years (2016-2019) climate data obtained from the Pangsuma Meteorological Station, Kapuas Hulu (Figure 1), it is known that Kapuas Hulu area which is the location of PT SR had quite high rainfall and temperatures in April and October, while the lowest in the month of July. Kapuas Hulu had an average temperature of 28°C with a range temperature of 23.1-33.3°C. This data could help to determine the best season for nurseries, acclimatization, and direct planting.

Figure 1. Climate graph of Kapuas Hulu

2. Materials and Methods

2.1 Materials
Data collection measurement tools consisted of digital calipers, walking sticks, GPS, lux meters, stationery, and camera. Soil sampling equipment consisted of the ground drill, plastic samples, and labels. The application used for data processing was Ms. Visio, Ms. Excel, Ms. Word, MiniTab16, RStudio, Avenza Map, and ArcMap 10.5. The primary data materials are rehabilitation enrichment plants and soil samples in the PT SR riverside area. The secondary data was obtained from year 2016-2019 climate data of
Meteorology and Geophysics Agency (BMKG) and secondary soil analysis data was obtained from Sucofindo Pontianak Laboratory in 2020 and SMART Research Institute-Analytical Laboratory in 2015.

2.2 Methods
2.2.1 Sampling technique
The main data included survival percentage and health of forest tree species; while supporting data was climate data, light intensity, and soil properties. The natural tillers were also observed at 2 m distance around the rehabilitation points (Figure 2). The dominance of forest tree species in rehabilitation area was mostly at the seedling and sapling level. Vegetation data was collected based on linear systematic sampling method which representatives adjusting the rehabilitation plant population per hectare. [10] Systematic sampling is a method using random numbers in the initial selection and then followed by a pattern of multiple figures. [11] In general, linear systematic sampling (LLS) is recommended to choose a representative value (n) that can be determined with certainty. The minimum sample number from all locations of 13 628 individual population were adjusted by Slovin formula [12]:

\[
S = \frac{N}{1+N \times e^2}
\]

where: \(S\) = sample, \(N\) = population, \(e\) = degrees of accuracy (0.05%)

In order to get a more significant number of representatives and fit the given deadline, the linear systematic sampling method was adjusted to the sampling intensity and number of individual rehabilitation plants in block concerned as listed in Table 1.

**Table 1.** Determination of the representative value of individual rehabilitation plants per planting block

| Rehabilitation tree population | Selected sample               |
|-------------------------------|-------------------------------|
| ≤ 4                           | Census [13]                   |
| > 4 and ≤ 31                  | 4 sample [13]                 |
| > 31 and ≤ 401                | Sampling intensity 10% [14]   |
| > 401                         | Sampling intensity 5% [14]    |

**Figure 2.** Sketch of oil palm and rehabilitation plants patterns and selected sample (0.12 ha)

- Oil palm, planting distance 9 x 8 m
- Rehabilitation plants, planting distance 4 m from oil palm
- Selected rehabilitation plant samples by linear systematic sampling method
- “Gawangan mati”, heaps of oil palm fronds
2.2.2 Measurement of diameter and height
Measurements were done on living plants by calculating the average diameter and height of plants.

\[ d = \frac{\sum d_i}{N_i} \times 100 \quad t = \frac{\sum t_i}{N_i} \times 100 \]  

(2)

where:
\( d \) = average diameter (cm)
\( t \) = average height (m)
\( d_i \), \( t_i \) = diameter and height of the \( i \)-plant
\( N_i \) = number of plants measured

2.2.3 Survival percentage
Data analysis was performed through the results of the calculation of the percentage of living plants with the following formula:

\[ H = \frac{\sum h_i}{N_i} \times 100 \% \]  

(3)

where:
\( H \) = percent of plant life (%)
\( h_i \) = number of \( i \)-living plants
\( N_i \) = number of \( i \)-plants planted

2.2.4 Health
Health of plants was determined by calculating the area and intensity of pest and disease attacks with the following formula:

\[ LS = \frac{\sum n}{N} \times 100 \% \quad IS = \frac{\sum (n_i x v_i)}{N x Z} \times 100 \% \]  

(4)

where:
\( LS \) = attack area (%)
\( IS \) = attack intensity (%)
\( n \) = number of plants attacked
\( n_i \) = number of plants attacked by \( i \) score
\( v_i \) = \( i \) score
\( N \) = total number of plants observed
\( Z \) = highest score

2.2.5 Measurement of light intensity
This action was determined the amount of sun light that could enter between oil palm canopy gaps. Measurements were done using lux meter which has symbol as lux (Lx) under with and without shade with 3x replications. The value obtained could help the selection of more suitable species based on whether or not resistant to shade (tolerant, intolerant, and semi-tolerant). Light intensity was measured in the morning (07.00-10.00) or afternoon (14.00-16.00) to obtain more significant irradiation value. However, there are also several conditions that affect as drizzle or cloudy weather. Irradiation conditions when raining have lower intensity compared to not raining conditions.

2.2.6 Soil sampling
Soil sampling was taken to determine the chemical properties of the selected soil from several locations through composite technique and quadrant method with 20 cm depth [15] that taken from 5 points of the planting block. Soil samples were analyzed at Sucofindo Pontianak Laboratory, West Kalimantan.
2.2.7 Data analysis
Survival percentage data was completed using the Mini Tab16 application. The height, diameter, and health data were presented in bar charts, lines, box plots, and tabulations using the Microsoft Excel application.

3. Results and Discussion
3.1 Survival percentage
Measurement of the percentage of survival was done based on an assessment of the species adaptability in each location. Based on representative sampling results at 846 rehabilitation points spread across 19 river border locations, 24 plant species were found with total of 627 individuals.

| No | Local name     | Scientific name               | Family        | Individual total | Dominance frequency (%) |
|----|----------------|-------------------------------|---------------|------------------|-------------------------|
| 1  | Ampening       | -                             | -             | 13               | 2.1                     |
| 2  | Cempedak       | Artocarpus champedens         | Moraceae      | 14               | 2.2                     |
| 3  | Durian         | Durio zibethinus              | Malvaceae     | 9                | 1.4                     |
| 4  | Jambu Monyet  | Melastoma marginata           | Melastomaceae | 72               | 11.5                    |
| 5  | Jengger        | Tristaniopsis bornensis        | Myrtaceae     | 12               | 1.9                     |
| 6  | Jengkol        | Archidendron jiringa          | Fabaceae      | 1                | 0.2                     |
| 7  | Karet          | Hevea braziliensis            | Euphorbiaceae | 1                | 0.2                     |
| 8  | Kawi           | Shorea balangeran             | Dipterocarpaceae | 132             | 21.1                    |
| 9  | Keladan        | Dipterocarpus gracillus       | Dipterocarpaceae | 1              | 0.2                     |
| 10 | Kopi           | Theobroma cacao               | Rubiaceae     | 1                | 0.2                     |
| 11 | Laban          | Vitex pubescens               | Lamiaceae     | 25               | 4.0                     |
| 12 | Manaung         | -                             | -             | 20               | 3.2                     |
| 13 | Markubung      | Macaranga gigantea            | Euphorbiaceae | 20               | 3.2                     |
| 14 | Mengadai       | -                             | -             | 7                | 1.1                     |
| 15 | Pulai          | Alstonia spp.                 | Apocynaceae   | 96               | 15.3                    |
| 16 | Pulai Pipit    | Alstonia angustiloba          | Apocynaceae   | 70               | 11.2                    |
| 17 | Purang         | Macaranga triloba             | Euphorbiaceae | 34               | 5.4                     |
| 18 | Rambutan       | Nephelium lappaceum           | Sapindaceae   | 1                | 0.2                     |
| 19 | Rengas         | Gluta renghas                 | Anacardiaceae | 1                | 0.2                     |
| 20 | Simpur         | Dillenia maxima               | Dilleniaceae  | 2                | 0.3                     |
| 21 | Tengkawang     | Shorea stenoptera             | Dipterocarpaceae | 13             | 2.1                     |
| 22 | Tepung         | -                             | -             | 19               | 3.0                     |
| 23 | Trembesi       | Samanea saman                 | Fabaceae      | 2                | 0.3                     |
| 24 | Ubah           | Syzygium darifolium           | Myrtaceae     | 61               | 9.7                     |

The most dominant species was kawi (Shorea balangeran) with 132 individuals (21%). The next dominant species comes from the Apocynaceae family named pulai rawa (Alstonia spp.) with 96 individuals (15%) and pipit pulai (Alstonia angustiloba) with 70 individuals (11%). Furthermore, from the Melastomaceae family, it was dominated by understorey, but for this species is able to grow high and part of woody species namely jambu monyet (Melastoma marginata) with 72 individuals (11%). Then, from the Myrtaceae family was ubah (Syzygium darifolium) with 61 individuals (10%). The average survival percentage of rehabilitation plants and natural tillers at PT Semitau Region was 74.11%.
In addition to internal factors, external factors such as disruption of human activities (the continuous harvesting activity in the rehabilitation area because the oil palm still produces fruit even though there was no special treatment has been given such as fertilization) are things that also affect the success of plant growth. The impact of oil palm harvesting activities such as the frond falling that hit the rehabilitation plant resulted from a plant in the failure to grow and die. The highest survival percentage was in Besar and Tekalong River with 100% total of living plants, while the lowest was in Rukam Hilir River with a 25% total percentage (Figure 3). The species that were known to be the most adaptive and had the highest population of each location were kawi (*Shorea balangeran*) from 6 locations, pulai rawa (*Alstonia spp.*) and ubah (*Syzygium darifolium*) from 4 locations, respectively (Figure 4).

### Figure 3. Percentage of plant life per location

### Figure 4. The dominance species in each location

#### 3.2 Plant height and diameter

The diameter of the three most adaptive plants, namely kawi, pulai, and ubah, had diversities that were not too significantly different. There were kawi and pulai species individuals which had quite different diameters that were shown by outliers. The median of the three plants showed in the range of 1 cm value indicating that the plant was in the seedling or sapling level (Figure 5). Figure 6 showed that the three species had quite different diversity values. Pulai had outlier at the smallest and largest which indicates that this species also had diversity in the seedling and sapling strata.

### Figure 5. Box plot of diameter of adapted plants

### Figure 6. Box plot of height of adapted plants
Table 3. Total data of height and diameter values

| Data                      | Height | Diameter |
|---------------------------|--------|----------|
| Maximal Value             | 6.50 m | 11.94 cm |
| Minimal Value             | 0.10 m | 0.07 cm  |
| Average Value (X)         | 1.90 m | 1.61 cm  |
| Standard Deviation (S)    | 1.30 m | 1.54 cm  |
| Coefficient Variance (CV) | 67.24 %| 95.50 %  |

The coefficient variance, both height and diameter showed medium-high value, 67.24% for height and 95.50% for diameter (Table 3). The higher coefficient of variance indicates that the spread of species was increasingly heterogeneous. This was evidenced by a total of 24 plant species were found. Based on the value of diameter distribution, it could be seen that the dominant species of rehabilitation area were in the diameter range of 0.06 - 2.05 cm, which indicates that the dominance value was at the seedling or sapling level of 470 individual. Based on the height distribution value, it was known that the dominant species were in the seedling stage as evidenced by the highest total in the range of 0.1-1.5 m, followed by dominance at the next interval of the sapling stage (>1.5 m). The highest value location was located on the Tekalong River with 2.56 cm of average diameter and 2.75 m of height. The worst location was in the Atin River with 0.77 cm of diameter and 0.65 m of height. The increasing of diameter and height plants were greatly influenced by the availability of water and nutrient balance in the soil, if there is a lack of that then the plants will experience deficiency [16].

![Figure 7. Diameter frequency distribution](image1)

![Figure 8. Height frequency distribution](image2)

3.3 Health

The health percentage of plants was measured by scoring the area of attack (LS) and the intensity of attack (IS) from suspected pests and diseases occurred. The total average value of PT SR rehabilitation area was 76.36% for pest attack area and the disease attack area was 32.19%, while for pest attack intensity was 42.36% and disease attack intensity was 18.60%. Based on the values obtained, it was known that pests had a greater role in causing damage compared to disease factors. Figure 9 presents the different symptoms of plant diseases due to pest and disease attacks. The information shows that plants that were attacked by pests might not necessarily be attacked by diseases. The pest attack was dominated by score 1 which showed that the percentage of attacks ranged between 26-50%. Although dominated by healthy plants, the highest disease attack was at score 1 which was mostly marked by the presence of sooty mold on the leaves. The sooty mold was caused by the Capnodium sp. fungi. which has the black mycelium scattered characteristics that covered the leaf surface [17]. Sooty mold fungus was associated with plant-eating insects so that black-colored hyphae were formed [18]. Species with the highest pest and disease resistance were pulai rawa (Alstonia spp.), kawi (Shorea balangeran), and laban (Vitex pubescens). The dominance of pest resistance
for pulai, kawi, and laban was 42%, 21%, and 16%, respectively. Meanwhile, the disease resistances were 21%, 26%, and 16%, respectively. The more resistance of these plants compared to another was due to the fact that they contain secondary metabolite compounds that function as defense mechanisms against pests and diseases [19-21]. Secondary metabolite of alkaloid base compounds causes pulai’s resistance of herbivorous pests [19]. Laban contains secondary metabolites consisting of alkaloids, flavonoids, terpenoids, and steroids which cause this plant to function as an antimicrobial and cure infection [20]. Kawi’s content of phytochemical compound functions as antioxidant and decreasing proliferation of disease [21]. The highest integration value between attack area and pest attack intensity was located in the Rukam Hilir River with 100% and 66.67% of the total, respectively. While the highest disease was in the Liut River with the 65.00% and 26.67% of acquisition value (Figure 10).

Figure 9. Frequency scoring of pests and disease

Figure 10. Health graph per locations

3.4 Soil chemical analysis

PT Semitau Region has peat and mineral soil types, but the composition which is fully spread in the rehabilitation area is mineral soil of latosol and podsolic. Besides considering the physical and chemical properties of soil, the calculation of light intensity is also needed as additional data to find out the species that are suitable for planting in each location. The average value of light intensity obtained from all locations of rehabilitation areas, with canopy was 542.88 Lx while without canopy was 2483.88 Lx.

Table 4. Soil chemical properties in selected locations

| Location       | Analysis Results |
|----------------|------------------|
|                | pH   | C-Organic (%) | N-Total (%) | C/N Ratio | KTK  |
| Tekalong1      | 5.42 | 3.08          | 1.69        | 1.82      | 4.90 |
| Atin1          | 5.49 | 3.65          | 0.84        | 4.35      | 2.40 |
| Besar2         | 3.84 | 1.41          | 0.12        | 11.75     | -    |
| Rukam Hilir2   | 4.88 | 1.55          | 0.13        | 11.92     | -    |
| Peniti Tayan2  | 4.90 | 1.57          | 0.12        | 13.08     | -    |
| Liut2          | 4.89 | 1.57          | 0.13        | 12.07     | -    |
| Rusa2          | 4.89 | 1.54          | 0.11        | 14.00     | -    |

1Sucofindo (2020) and 2SMART Research-Institute Analytical Laboratory (2015)

The value of light intensity was useful for determining the species suitability of tolerant, intolerant, or semi-tolerant. Based on Table 4 it is known that the C/N ratio at the location was quite varied. The year
difference in the analysis of soil chemical properties greatly influenced the value of the C/N ratio. Tekalong and Atin Rivers which were analyzed directly at Sucofindo Laboratory in 2020 had a lower value of C/N ratio, 1.82, and 4.35, respectively. Meanwhile, Besar, Rukam Hilir, Penayan Tayan, Liut, and Rusa Rivers which were analyzed by secondary data from the SMART Research Institute-Analytical Laboratory in 2015 showed higher C/N ratio with a lower value of N-total ranged between 0.11-0.13. The difference significant in the C/N ratio showed that there has been a decomposition of soil organic matter within 5 years. This was also certainly influenced by the presence of rehabilitation plants that have been planted since 2016, it could be seen that N-total increasingly significant with the 0.11-0.13 range to the 0.84-1.69 range. Generally, there are similarities of symptoms caused by disease and nitrogen deficiency, the leaves show pale and yellowish color. The symptoms of N deficiency are first seen on older leaves, namely pale green leaves then chlorosis appears into bright yellow or pale and subsequently experience necrosis [22].

3.5 Implications for recommendation species
Consideration for selecting suitable forest tree species was done based on the analysis of the variables that have been discussed. These species were kawi (Shorea balangeran), pulai rawa (Alstonia spp.), and ubah (Syzygium darifolium). Kawi or was known as red meranti or balangeran is a local species which only spread naturally on the Sumatra and Kalimantan islands, Indonesia. Kawi could grow well in areas of peat swamp forest reaching 20-25 m of height, 50 cm of diameter, and producing damar (resin). The field reality showed that kawi could still grow even in submerged areas. Pulai has natural distribution in almost all regions of Indonesia such as Java, Sumatra, Bali, Nusa Tenggara, Maluku, South Kalimantan, West Kalimantan, and Irian Jaya. Pulai is scattered in peat swamp forests, tidal areas, and dry areas with varieties of heights. The field reality showed that this species is able to re-grow through lateral branches even though it has been affected by the falling frond of oil palm. Ubah is a species that grows mostly in peat swamp. This plant comes from the Myrtaceae family with Syzygium genus. This species was also found quite a lot in the rehabilitation area as natural tillers.

4. Conclusion
The best survival rate of three plants species for further development is kawi (Shorea balangeran), pulai rawa (Alstonia spp.), and ubah (Syzygium darifolium) which is 45% of total individual plants that have survived. Information on the type of adaptation potential is expected to be useful information for increasing successfully riversides through replication technique of rehabilitation area of oil palm plantation.

As a recommendation, further research is needed based on the best adaptability of the three forest tree species so that they can be developed for future replication of mass planting in the field.

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