Agroforestry farming system as peatland restoration efforts in Central Kalimantan, Indonesia

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**Abstract.** Peatland degradation is caused by various factors, such as excessive drainage and frequent fires. The Government of Indonesia established the Peatland Restoration Agency in 2016 to accelerate peatland restoration and peat's hydrological function. This study analyses agroforestry in priority areas for peat restoration. The results showed that farmers applied agroforestry cultivated land by combining jelutong (*Dyera costulata*) with many types of commercial plants at a spacing of 3 m x 6 m. Growth of Jelutong showed good performance with an average growth of 1.42 ± 0.49 cm yr\(^{-1}\) diameter and a height of 91.33 ± 36.77 cm yr\(^{-1}\). The crops cultivated with jelutong included luffa (*Luffa acutangula*), bitter gourd (*Momordica charantia*), leek (*Allium ampeloprasum*), and chilli (*Capsicum annuum*). The average income per planting period ranging from IDR 850,000 up to IDR 19,250,000 for a 1000 m\(^2\) planting area. The best income and cost ratio (R/C) is bitter gourd farming with a value of 7, eggplant, luffa, and waxy corn with a value of 3, while the smallest is leek with a value of 2. Some farmers can develop their agriculture in the form of planting areas or agricultural varieties. The formation of agricultural capital has now begun with monthly contribution obligations at regular monthly meetings.

1. **Introduction**

Peatlands, which cover one-third of global wetlands [1], are important ecosystems for biodiversity conservation, climate regulation, and human well-being [2]. Peatlands are characterized by the accumulation of organic matter from dead and decaying plant debris under water-saturated conditions. The world's total peatland area of around 400 Mha or 3% total land [3] and as much as 31-46 Mha or about 10-12% of the world's total peat, is located in tropical areas [4][5]. More than half (24.8 Mha) of the global area of tropical peatlands are in Southeast Asia (56%), mostly in Indonesia and Malaysia. Due to the considerable thickness (average > 5 m) of peatlands in these two countries, they contain 77% of the total carbon storage of tropical peat [6].

In general, peatlands in Indonesia have been utilized. Poor peatland management can lead to land degradation and forest and land fires. In Southeast Asia, land-use conversion of around 10 million ha of peatlands results in annual emissions of 132-159 Mt C year\(^{-1}\) from peat oxidation and increased incidence of peat fires, which not only add to the burden of GHG emissions but also threaten human health and livelihoods [7][8]. Besides, loss of peat through oxidation and fire results in land subsidence and an increased risk of flooding [9][10][11] on drained peat. Subsidence may occur due to the...
combination of consolidation and decomposition [10][12][13]. However, tropical peat, especially in Indonesia, has experienced a lot of degradation by mismanagement of peatlands and forest and land fires. Humans still cause almost every dry season, forest fires, and the mainland in the environment and the peatlands’ inept management. The Peatland Restoration Agency established by the Government has the task of carrying out peat restoration through the 3R approach (re-wetting, replanting, and revitalization of livelihood), and since 2017 it has carried out many restoration activities. Successful restoration pays attention to ecological aspects and the surrounding community’s welfare with interest in peatlands.

It is often less attractive for vegetation restoration activities because it has a long period and has not provided economic benefits for the community. Agroforestry is an alternative that can be proposed for peatland restoration activities. Agroforestry is an ecological system-based natural resource management by integrating trees with other crops to provide social and economic benefits and environmental benefits. Agroforestry improves soil quality, agricultural production, and sustainable forestry, which is closely related to income. Agroforestry productivity is higher than monoculture and is evenly distributed throughout the year and provides benefits because one crop’s failure can be covered by another [14]. Losses due to market price fluctuations can be overcome compared to monoculture, as well as balance and stability and equality of farmer income is guaranteed, and agroforestry income provides a proportion of 33-59% and income from agroforestry plays a role in reducing poverty and increasing income distribution [15]. The development of agroforestry in forest stands in West Java shows that for an area of 0.25 ha, it generates IDR 4.3-17.1 million [16]. Research in Sumber Agung Village, Bandar Lampung shows an average agroforestry contribution of IDR 10,660,989/family/month and when compared with the Bandar Lampung minimum wage standard [17]. In South Sulawesi, agroforestry's economic contribution in farmers’ yards is between 43.27 - 49.06% of total farmer income, which contributes to farmer income and environmental sustainability and biodiversity [18]. In Tanzania, agricultural production and net income are greater in farm households that apply agroforestry and contribute significantly to increased yields and income and reduce household poverty levels [19]. Cutler et al. [20] explained that the implementation of agroforestry in Mamuju, West Sulawesi provides an excellent economical rate of return (ERR), namely 10 - 28.7% with an income level of between IDR 7,000,000 - 12,500,000 ha\(^{-1}\). The main component of agroforestry, Jelutong rawa (Dyera polyphylla (Miq.) Steenis) is a type of peat swamp plant, in the regions of Sumatra and Kalimantan. Based on its original growing location, this plant grows on inundated land. Jelutong rawa is a tree plant recommended in peat restoration efforts and is suitable for development as a commodity in an agroforestry system [21]. The wood is processed into blocks/boards, plywood, and wood pulp; besides being taken the sap is either in the form of blocks/sheets that can be used as an insulator for electrical cables, tires, and gum, and in the form of resin which can be used as cosmetics, varnishes, and essential oils [22]. The development of Jelutong with an agroforestry system has a better economic viability value than monoculture. A study showed that Jelutong and rubber tree agroforestry systems have NVP of 69,799,388, BCR of 8.68, and IRR of 29% [21]; and another revealed NVP of 9,247,417, BCR of 5.35, and IRR of 24.1% [23].

This study examines the growth rate of Jelutong, perceptions, and analysis of farming carried out on agroforestry cropping patterns as part of the restoration pattern of tropical peatlands.

2. Methods

The research was carried out on peatlands in Kalampangan Village, Palangka Raya, Indonesia, in a location that was cultivated for the first time (owned by farmer 1, namely Pak Parni) and in a fairly developed agroforestry area (owned by farmer 2, namely Pak Taman), as shown in Figure 1. After clearance, the land is first processed using a hand tractor, and then wood waste is cleared. Furthermore, the planting of a specific peat tree species, namely Jelutong, is carried out in combination with dragon fruit and vegetables. Jelutong cultivation is carried out at a distance of 6 m x 3 m. The complete planting is presented in Figure 2a. For Jelutong cultivation, the basic fertilizer is given in the form of chicken manure as much as 1.7 kg per planting hole of 50 cm deep, and let stand for 15 days. If it doesn't rain, then watering is performed. Observations at the new agroforestry location were carried out on Jelutong plant growth, including stem diameter, number of leaves, and plant height. For vegetables, cultivation was carried out by farmers who choose the type of plant according to the farmer’s wishes. The recording
is carried out on the intercropping cultivation technique, including the input used and the farming business analysis. For developed agroforestry locations (Pak Taman's location, farmer 2), the existing plants' (7-8 years old) stem diameter measurements and analysis of the agroforestry pattern farming were carried out.

![Figure 1. Research location](image)

Vegetable farming data was collected by observing, observing, and interviewing farmers. The data collected includes farming costs incurred from planting to harvest, data on agricultural production, and commodity prices. While the method of farming analysis used is:

- **Income Analysis.** Farming income was analyzed based on vegetable farming's income and costs by calculating the difference between revenue and production costs [24].

  \[
  I = TR - TC \tag{1}
  \]

  \[
  I = \text{Income} \\
  TR = \text{Total Revenue} \\
  TC = \text{Total Cost}
  \]

  \[
  TR = Q \times PQ \tag{2}
  \]

  \[
  Q = \text{Production} \\
  PQ = \text{Price}
  \]

- **R / C Ratio Analysis.** The feasibility of farming is analyzed based on the ratio of revenue to cost [24].

  \[
  \frac{R}{C}\text{ Ratio} = \frac{TR}{TC} \tag{3}
  \]

  \[
  R = \text{Revenue} \\
  C = \text{Cost} \\
  TR = \text{Total Revenue} \\
  TC = \text{Total Cost}
  \]

  If value: \( \frac{R}{C} > 1 \), then the farming is profitable. If \( \frac{R}{C} < 1 \), then farming is not profitable or losing. If \( \frac{R}{C} = 1 \), then the farming is at the break-even point. That is, the total cost is equal to the total revenue.
3. Results and discussion

3.1. Jelutong growth

Jelutong, which is cultivated in this agroforestry area, was planted in December 2017 (Farmer 1). Stem diameter, plant height to the last branch, height to the tip of the shoot, and the number of leaves were measured in plants aged 3, 5, 8, 12, and 24 months (Figure 2). All measured growth indicators for Jelutong show fairly good growth. Jelutong plants showed good physical growth, i.e., after the age of 2 years, they have an average plant height of 2 m. Jelutong growth showed good performance with an average growth rate of $1.42 \pm 0.49 \text{ cm year}^{-1}$ for tree diameter with a polynomial growth pattern ($R^2 = 0.98$) [25], and $91.33 \pm 36.77 \text{ cm year}^{-1}$ for tree height with an exponential growth pattern ($R^2 = 0.92$). The increase in Jelutong leaves number during the study period to one year was $4.4 \pm 2.8$. Horticultural crops show fairly good physical growth, although cultivation on new land requires more production inputs (especially lime and manure) compared to land that has been repeatedly used for horticultural cultivation. The application of lime and fertilizer to horticultural plants provides benefits to jelutong plants, i.e., jelutong plants do not need additional fertilization. Fertilization of Jelutong plants is carried out at the time of initial planting at a dosage of 1-1.5 kg of manure/tree. At Farmer 1, Jelutong trees were not given any more fertilizers other than basic fertilizer in manure and only utilized the fertilizers applied on the horticultural row. However, it is possible for the current age that the Jelutong roots have not reached the horticultural row's location.

![Figure 2](image-url)

**Figure 2.** Stem diameter, height to the top stem, height to top leaf, and number of leaves of Jelutong trees planted in agroforestry

In agroforestry locations with Jelutong trees planted for 7-8 years (Farmer 2, Pak Taman), the average diameter of Jelutong trees was $14.85 \pm 3.39$, the maximum diameter was 21.02 cm, and the minimum diameter was 7.13 cm. Farmer 2 used the fallen leaves as fertilizer. The roots have reached the annual crop cultivation area, but the input for seasonal crops is also low.
3.2. Agroforestry model

On Farmer 1's land, Jelutong was planted at a distance of 6 m x 3 m, and between the Jelutong rows, horticultural crops such as leeks, mustard greens, bitter gourd, purple eggplant, luffa, and chilies were planted. In the Jelutong plant pathway, between the Jelutong trees, it is planned to plant dragon fruit with a spacing of 3 m. The first planting of dragon fruit was not successful considering the limited manpower for dragon tree maintenance, which must be done intensively. Since July 2020, it is planned to increase vanilla cultivation using the Jelutong tree's shade. Currently, Vanilla nurseries are being carried out (Figure 3c). In choosing this combination plant, it is possible because vanilla is a plant that requires shade. Besides, this plant's yield is quite promising because the average income of vanilla farmers is IDR 12,805,425 per ha per year [26]. Because it is an efficient crop, vanilla does not use much nutrients from peatlands. Vanilla only produces when the plants are between 2.5-3.5 years old [27]. Therefore, to provide short-term income, annual crop cultivation is carried out. Generally, in the Kalampangan Village Central Kalimantan peat area, these crops are chilies, water spinach, spinach, and leeks, which is the main crop source of income for peatland farmers [28]. The cropping pattern on Farmer 2's land is 7-8 years old Jelutong trees with a spacing of 6 m x 3 m, with a variety of intercropping including maize, cassava, chilies, and red ginger (Figure 3b).

Figure 3. Agroforestry pattern and vanilla nursery

Vegetable commodities cultivated by farmers are bitter gourd, purple eggplant, luffa, chilies, cassava, corn, and green onions. All commodities show good growth performance, produce well, and the yield can be marketed. The average planting area was 1,376 m², with the largest area of 4,050 m² for cassava plants and the narrowest of 200 m² for luffa and purple eggplant. Plant age varies between 2-12 months, with the youngest being corn and the highest being cassava. Meanwhile, the harvest age ranges from 2 months to 8 months after planting. The harvested crops are cassava, leeks, and corn; other crops can be harvested repeatedly for up to 2 months after the first harvest. Good plant maintenance, including pest control and intensive fertilization, will extend the life of the crop. The market price also influences the farmers' decision to extend the harvest period. When the selling price is low, the farmers tend not to extend the harvest period because they will experience maintenance costs losses.

Table 1. Analysis of vegetable farming in an agroforestry area of 1000 m² for one planting season

| Description | Unit | Bitter gourd | Eggplant | Luffa | Chilli | Cassava | Waxy corn | Leek |
|-------------|------|--------------|----------|-------|-------|---------|----------|------|
| Production  | kg   | 488          | 2.625    | 4.746 | 250   | 1,814   | 169      | 1,267 |
| Price       | IDR/kg | 6.000      | 6.000    | 6.000 | 20.000| 4.000   | 8.000    | 20.000|
| Total Cost  | IDR  | 471.667    | 5,175.000| 9,225.000| 990.000| -       | 502.222  | 3,151.333|
| Income      | IDR  | 2,925.000  | 15,750.000| 28,475.000| 5,000.000| 7,257.284| 1,352.222| 25,333.333|
| Revenue     | IDR  | 2,453.333  | 10,575.000| 19,250.000| 4,010.000| 7,257.284| 850.000  | 12,182.000|
| R/C         |      | 7           | 3        | 3      | 5     | -       | 3        | 2     |

The highest vegetable productivity was in luffa (47.46 tons ha⁻¹), followed by purple eggplant (26.25 tons ha⁻¹) and cassava (18.14 tons ha⁻¹), while the lowest production was waxy corn with a productivity of 1.69 tons ha⁻¹. Leek plants have a productivity of 12.67 tons per ha, followed by bitter gourd 4.88 tons ha⁻¹ and chilies 2.5 tons ha⁻¹. Nationally, bitter gourd production can reach 30-50.2 tons ha⁻¹ [29], while the luffa is 8-12 tons ha⁻¹ [30]. Meanwhile, waxy corn gives little yield because the cobs produced
are relatively smaller than other maize types, and the production is low. According to previous research [31], waxy corn in Indonesia is commonly a local variety with low yield potential (less than 2 tons/ha)\(^1\), small cobs with a 10-11 mm diameter, and is very sensitive to downy mildew.

The results of the income analysis show that the highest level of income at one planting season is the luffa plant with a value of IDR 19,250,000, and the lowest income was on waxy corn with a value of IDR 850,000, with a monthly income of between IDR 425,000, 6,415,000. With such variations in income per month, farmers need to make cropping patterns with various types in one growing season to provide maximum income. The R/C ratio analysis shows a value above 1, which means that vegetable farming between Jelutong stands provides an advantage. The largest R/C value is at Bitter gourd plants showed an R/C ratio of 7, purple eggplant, luffa, and waxy corn with an R/C ratio of 3, the lowest was leek with a value of 2. An exception was cassava plants because they were planted just like that, did not require any cost for fertilizers and pesticide, and the planting material (cuttings) did not have to be bought. Farming analysis with vegetable cropping patterns on peatlands showed R/C ratio of bitter gourd and luffa plants with cucumber-bitter-gourd-long bean cropping patterns, and cropping patterns of cucumber-luffa-long beans showed R/C ratios of 1.28 and 1.27, respectively [32]. The high R/C ratio in this research's agroforestry system is because labor costs from within the family and watering costs are not considered. Besides, intensive maintenance may cause a longer harvest period and more yield.

4. Conclusion

Jelutong planted together with horticultural crops in the agroforestry system shows good growth. The application of fertilizer to horticultural crops provides benefits for the growth of Jelutong plants. Horticultural crops can grow well by providing several production inputs, such as lime, manure, and chemical fertilizers. Horticultural crops planted together with Jelutong provide a good income, which is an average of Rp. 425,000 - Rp. 6,415,000 per month on a land area of 1,000 m\(^2\), with an R/C rate > 1. The farmers can carry out restoration efforts by revegetating agroforestry farming systems by planting several types of horticultural crops in one season to get a variety of income.

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