The productivity increasing of peatlands on community land by multi-cropping model in Riau Indonesia

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Abstract. Development and protection of peatlands become important things to reduce land damage, such as peatland fires, and can increase economic value for farmers. This research aims to evaluate the development of peatlands which friendly. The conduct was August 2017 to June 2019 in Merbau, Bunut Regency-Province of Riau, Indonesia. The area has 3 peatlands; those are shallow, medium, deep, and enrichment peat. The results showed that multi-cropping could be cultivated to some plants, those are Liberika coffee, rubber, and Areca nut for annual plants. Besides that, a pineapple could be cultivated among annual plants. Monkeys and wild boars are seriously affecting independence to cultivation. Community and farmers approach with public figure become the key to land management without peatland fires.

1. Introduction
Indonesia is a country that has the largest peatland in the world. The peatland is around 21 million hectares or more than 10% of Indonesia's area with distribution in Sumatra, Kalimantan, and Papua [1] [2] [3] [4]. Peatland is land that has a C-organic content of more than 18%, so it has a unique characteristic compared to other lands. The ability of peatland to save water is very high [2] and [5]. These characteristics became problem when the water content decreases drastically which caused by land clearing and long drought. The subsequent impact could lead to degradation of peatlands due to increased soil acidity and forest fires which is not only became a national issue but also became an international issue.

In 2013 and 2015 peatland fires have become an international issue because they caused smoke disturbances and other widespread impacts [6]. Therefore, the government have been trying to restore land function or carry out restoration and rehabilitation activities of peatland ecosystems through the Peat Restoration Agency (BRG). Peatland issues must be addressed immediately to conserve peatlands as well as the ecosystems embedded in them. Some of the effort for restore and rehabilitate peatlands by applying Paludiculture and Agroforestry. Paludiculture is a technique of adaptation to plant species, especially local plants, which are in accordance with the environmental conditions or ecosystems of peatlands, such as Sago, Meranti, Areca palm, Jelutung and others [7] and [8]. While Agroforestry is a technique of cultivating annual crops under stands of tall plants or forest plants [9]. Furthermore, agrosilvofishery technology provides a choice of community-based peatland management that is more integrated and more environmentally friendly. The Agrosilvofishery technology offered is expected to be an option for improving the pattern of peatland utilization that has been practiced by the community.
The application of these techniques is very dependent on the condition of each land. In addition, it is also expected that the yield or production of these plants will be able to provide benefits and income, especially for the local community continuously or in other ways able to preserve the environment and its benefits in a sustainable or sustainable manner.

2. Materials and Methods
The implementation of Paludicultural based plant enrichment in Riau Province was carried out in the area of Merbau Village, Bunut District, Pelalawan Regency on August 2017-June 2019. Merbau Village was chosen for the pilot project for the implementation of action research after going through a field survey by gathering information on potential land as a paludiculture demonstration plot on peatland. Furthermore, a review of land used for demonstration plots was covering an area of +2.5 ha on shallow or thin peatland (0° 14’47.3” N and 102° 12’ 98.3” E), +2.5 ha on medium peatland (0° 15’1.9” N and 102° 13’ 17.3” E), +2 ha on deep or thick peatland (0° 14’32.0” N and 102° 13’ 43.5” E), and +3 ha on enrichment deep peatland (0° 15’ 57.2” N and 102° 13’ 39.6” E).

2.1. Materials
Location determination as a demonstration plot was based on farmer information’s and initial analysis. Shallow peatland had less than 1 meter depth; medium peatland had 1 – 2 meters depth; and Deep peatland had more than 2 meters depth. Demonstration plots was done using an excavator machine and the outer boundary determined by small ditch. For enrichment, the deep peatland which used that was planted by rubber trees. The rubber trees had more than 2 meters tall and 2 – 3 meters planted distance of each.

2.2. Methods
Dissemination activities and group discussion forums were conducted to provide information to the public regarding the planned activities to be carried out this year as well as to gather information relating to the planned integration of the development and protection of peatlands in Merbau Village in first time. Through Participatory Rural Appraisal (PRA) implemented in 2017, the community program already had a map of potential, partnership network maps, knowledge, skills, and assets obtained through action research that can be developed for the next period. Based on ‘capital’ in the first year, the focus of empowerment in the second year was how to develop ‘capital/assets’ that had been owned by the community could be developed further. This is the basis for determining the method of action research in the second year (2018) to prefer the approach of active community participation which gives more space to the community to be able to develop their potential. The PRA result were decided seven commodities plant which would be planted and where the peatland location in the first year. The commodities were rubber tree, Banana, Areca palm, Local Coconut, Hybrid Coconut, Liberika Coffee, and Sago palm for shallow, medium and deep peatlands. Moreover, the pineapple would be planted in enrichment peatland under rubber trees which had been planted before by owner.

The planted method used intercropping method which some annual trees was filled by season crops or Liberika Coffee tree. The combinations were two columns Liberika Coffee tree inter a column Rubber tree; two columns pineapple crops had inter a column Hybrid Coconut tree; Raja Banana tree had belong a column Areca palm; three columns pineapple crops had belong a column local coconut tree; and inter Sago palm had been filled a column Raja Banana and four columns pineapple crops. The plant distance shows Table 1.
Table 1. The plant distance on the plot demonstration

| Commodity crop/tree       | Distance planted (meters) |
|---------------------------|---------------------------|
| Sago palm                 | 8 x 8                     |
| Hybrid Coconut            | 5 x 6                     |
| Local Coconut             | 6 x 6                     |
| Areca palm                | 3 x 3                     |
| Liberika Coffee           | 3 x 3                     |
| Rubber tree               | 3 x 7                     |
| Raja Banana               | 2 x 2                     |
| Pineapple                 | 2 x 2                     |

The planted distance was determined for inter columns and inter rows in similar tree or crop. The crop or filled crops or trees had short distance than annual trees.

3. Result

The results of the evaluation obtained several results specifically regarding the number of surviving plants from plants planted in 2017 as in Table 2 and Table 3. This evaluation is the basis for developing and protecting peatlands as well as efforts to increase community income.

Table 2. Soil characteristics from laboratory analysis

| Location      | pH  | C organic (%) | N total (%) | C/N  |
|---------------|-----|---------------|-------------|------|
| Shallow peatland                                      |     |               |             |      |
| Top soil (1)  | 4.45| 45.85         | 0.95        | 48.52 |
| Top soil (2)  | 4.72| 37.35         | 0.82        | 45.60 |
| Top soil (3)  | 4.51| 39.53         | 0.91        | 43.44 |
| Sub soil (1)  | 3.68| 37.13         | 0.84        | 44.20 |
| Sub soil (2)  | 4.73| 36.68         | 0.63        | 58.22 |
| Sub soil (3)  | 4.21| 38.86         | 0.74        | 49.81 |
| Medium peatland                                      |     |               |             |      |
| Top soil (1)  | 4.13| 41.60         | 0.63        | 66.03 |
| Top soil (2)  | 3.51| 36.01         | 0.68        | 52.76 |
| Top soil (3)  | 3.92| 38.85         | 0.68        | 57.13 |
| Sub soil (1)  | 4.16| 34.45         | 0.89        | 38.60 |
| Sub soil (2)  | 4.12| 33.33         | 1.05        | 31.74 |
| Sub soil (3)  | 4.11| 33.98         | 0.95        | 35.77 |
| Deep peatland                                         |     |               |             |      |
| Top soil (1)  | 3.59| 32.88         | 0.89        | 36.84 |
| Top soil (2)  | 3.29| 44.96         | 0.68        | 65.88 |
| Top soil (3)  | 3.44| 39.28         | 0.88        | 44.89 |
| Sub soil (1)  | 3.80| 34.45         | 0.68        | 50.48 |
| Sub soil (2)  | 4.10| 40.26         | 0.89        | 45.11 |
| Sub soil (3)  | 4.05| 37.55         | 0.85        | 44.18 |
| Enrichment peatland                                   |     |               |             |      |
| Top soil (1)  | 3.86| 40.39         | 0.74        | 55.69 |
| Top soil (2)  | 4.09| 43.09         | 0.94        | 45.84 |
| Top soil (3)  | 3.96| 39.82         | 0.84        | 47.40 |
| Sub soil (1)  | 3.91| 33.33         | 0.84        | 39.68 |
| Sub soil (2)  | 4.27| 38.25         | 0.82        | 46.70 |
| Sub soil (3)  | 4.19| 37.95         | 0.83        | 45.72 |
The result of soil characteristic analysis (Table 2) shown that soil organic matter had more than 30% classified into organic soil or peatland. The acidity soils from all location belong to 3.29 to 4.73 which were classified as acid to very acid. The results of the analysis shown that the peatland at the location of the activity was classified as acid to very acidic. Acidic peatlands which have a pH value of 4.5 to 5.5. Soil samples included in the classification of acid soils are in a part of shallow peatlands. While others have a soil pH value of less than 4.5, this is included in the classification of highly acid soils. However, the pH value of shallow peatlands was close to very acidic soil classification. The upper layers of shallow peatland tend to higher pH than those of thick peatland [10].

Table 3. Results of evaluation of plant growth on peatlands

| Vegetation     | Early seed | Re-plant | Lethal | Sprout | Fine | Weak |
|----------------|------------|----------|--------|--------|------|------|
| Shallow peatland |            |          |        |        |      |      |
| Rubber tree    | 116        | -        | 74     | 64%    | 42   | 36%  | 42   | 36%  | 0    | 0%   |
| Banana         | 350        | -        | 296    | 85%    | 54   | 15%  | 22   | 6%   | 32   | 9%   |
| Areca palm     | 233        | 145      | 198    | 52%    | 180  | 48%  | 165  | 44%  | 15   | 4%   |
| Local Coconut  | 83         | -        | 35     | 42%    | 48   | 58%  | 33   | 40%  | 15   | 18%  |
| Hybrid Coconut | 140        | -        | 140    | 100%   | 0    | 0%   | 0    | 0%   | 0    | 0%   |
| Coffee         | 400        | 339      | 404    | 55%    | 335  | 45%  | 360  | 49%  | 40   | 5%   |
| Sago palm      | 50         | 30       | 78     | 98%    | 2    | 3%   | 1    | 1%   | 1    | 1%   |
| Medium peatland |          |          |        |        |      |      |
| Rubber tree    | 116        | -        | 41     | 35%    | 75   | 65%  | 75   | 65%  | 0    | 0%   |
| Banana         | 350        | -        | 315    | 90%    | 35   | 10%  | 15   | 4%   | 20   | 6%   |
| Areca palm     | 250        | 139      | 139    | 36%    | 250  | 64%  | 210  | 54%  | 40   | 10%  |
| Local Coconut  | 83         | -        | 63     | 76%    | 20   | 24%  | 13   | 16%  | 7    | 8%   |
| Hybrid Coconut | 140        | -        | 140    | 100%   | 0    | 0%   | 0    | 0%   | 0    | 0%   |
| Coffee         | 400        | 334      | 374    | 51%    | 360  | 49%  | 315  | 43%  | 45   | 6%   |
| Sago palm      | 50         | -        | 50     | 100%   | 0    | 0%   | 0    | 0%   | 0    | 0%   |
| Deep peatland  |            |          |        |        |      |      |
| Rubber tree    | 116        | -        | 17     | 15%    | 99   | 85%  | 99   | 85%  | 0    | 0%   |
| Areca palm     | 233        | 35       | 98     | 37%    | 170  | 63%  | 158  | 59%  | 12   | 4%   |
| Local Coconut  | 83         | -        | 76     | 92%    | 7    | 8%   | 5    | 6%   | 2    | 2%   |
| Hybrid Coconut | 140        | -        | 140    | 100%   | 0    | 0%   | 0    | 0%   | 0    | 0%   |
| Coffee         | 400        | 115      | 120    | 23%    | 395  | 77%  | 300  | 58%  | 95   | 18%  |
| Sago palm      | 50         | 30       | 80     | 100%   | 0    | 0%   | 0    | 0%   | 0    | 0%   |
| Enrichment peatland |    |          |        |        |      |      |
| Pineapple      | 4.300      | -        | 400    | 9%     | 3.900| 91%  | 3.700| 86%  | 200  | 5%   |

Based on actual peatland that had less than pH 4, some of those indicated presence of pyrite layers. The most potential pyrite was located on deep peatland. For this reason, on deep peatlands, it was recommended to always in flooded condition to avoid pyrite oxidation that can become poisoning to plants. Inundation was monitored through groundwater level, so water level observation wells are made
at each location. The presence of flood gates on the channel was a priority, so the water level can be controlled. The total nitrogen content of peatland was very high, with levels of 0.51–0.75 for high caliphate and more than 0.75 for very high classifications based on soil fertility classification. This shows that the decomposition process runs quite well or the source of high material so that the total nitrogen content is high. However, the results of the calculation of the C/N ratio was high than other soil [11], which was indicated the decomposition process had not been running fast. it is suspected that the degree of decomposition process were in anaerobic conditions dominantly.

Based on the results of the evaluation, it shown that the plants that could survive in Fine condition on shallow peatlands, medium peat and deep peat were Rubber trees, Areca palm and Liberika Coffee (Table 3). In addition, enrichment of Pineapple plants on enrichment land also has very fine growth results. This indicates that these plants are suitable for development on peatlands. Other plants, such as Local Coconut and Hybrids and Sago palm could be survive, so they were suitable to cultivate by farmers. The problem were came from monkey and wild boar pests. In addition, high water inundation conditions or floods often occur in the rainy season, which was become a barrier to cultivation on these peatlands.

4. Conclusion
The use and protection of peatlands can be directed by implementing appropriate farming systems and suitable crops such as areca, rubber, liberica and pineapple on shallow, medium as well as on deep peatland areas. The land clearing can be done without burn method and impact to environment degradation. The paludiculture intercropping can increase farmer capital and awareness to peatland conservation and sustainable. Those methods also keep plant diversity in peatland and make sustainable agriculture based on environmentally friendly with eliminate dependency to a commodity, like palm oil tree or rubber tree.

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