A study of sustainable peat cultivation implemented by the community of Tumbang Nusa Village, Central Kalimantan

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Abstract. Peatlands have enormous potential to produce food sources for supporting population growth. Farmers generally prefer plants that can adapt to changing conditions. However, challenges remain, such as limited knowledge of local community about peatlands' function and management. Local community practices endogenous knowledge to manage peatlands, but it is rarely documented as best practice for peatlands management in Indonesia. This study aims to understand endogenous management implemented by local community for sustainable peat cultivation. The management is currently considered as the best solution to solve problems related to peatlands management. The study was carried out in Tumbang Nusa Village, Pulang Pisau Regency, Central Kalimantan Province, using a semi-participatory approach with a stratified purposive sampling for selecting participants of in-depth interviews and field observations. An investigation of endogenous management related to biophysical aspects that determines sustainability was done by identifying main characteristics of peatlands in the dry season. The data were analyzed qualitatively by using Use Value. The results show that the community applied agroforestry systems interspersed with introduced plants. There were seven patterns implemented by the community, including pineapple-forest crops-seasonal fruit-based, rubber-forest crops-seasonal fruit/food-based, a combination of forest plants, a combination of forest plants-annual/food crops, and a combination of annual crops. The seven patterns based on the local wisdom are suitable for peatlands. It is in accordance with modern peat management which considered as the form of a pure Paludiculture and an intensive semi Paludiculture.

1. Introduction
Peat contains more than 90% water in each unit volume and can store and supply water for the surroundings. It also plays numerous roles: providing food stock, habitat of animals and plants, water regulator, preventing seawater intrusion, and controlling climate change [1,2].
Peatlands have great potential to provide for food sources for supporting population growth. Local people prefer certain types of plants based on their adaptability with local conditions, such as sago, pineapple, rambutan, areca nuts, and jelutung. However, peatlands utilization for food crops faces two main issues, i.e. socio-economic benefits of food production and the function in maintaining environmental quality [3].

There are challenges in peatland management due to limited knowledge of local community about the function and appropriate peatland management. This can be observed from the lack of understanding of the community on the complexity of peatland management system and the importance of its function. For instance, the community does not aware of the importance of implementing paludiculture as the best systems to overcome peatlands management problems.

The principle of paludiculture is selecting native plants species for cultivation, so draining off peatlands is not necessary. This would provide multiple benefits, including economic benefits and long term biomass production (plant biomaterials) [4].

Understanding aforementioned conditions become imperative to find the right solution through investigating native peat-plant species which are commonly cultivated by local community. The species are generally adaptive to peatland conditions, economically beneficial and harmless for peatland ecosystem. Therefore, a study discussing on the complex efforts being implemented by local community is required to select the best cultivation for sustainable peatland management.

2. Methods

The study was conducted in Tumbang Nusa Village, Pulang Pisau Regency, Central Kalimantan Province. Using a semi-participatory approach with a stratified purposive sampling through in-depth interviews [5] and field observations to 32 heads of families who work as farmers on peatlands to investigate biophysical variables that determine sustainability by identifying the main characteristics of peatlands in the dry season. Furthermore, the data was analyzed qualitatively by using use value [6].

3. Results and discussion

Various efforts to restore damaged peat ecosystems continue to be carried out through rehabilitation or restoration activities, known as 3Rs; rewetting, revegetation, and revitalization [2]. Paludiculture is a method used in peat restoration for sustainable peatland management. Paludiculture comprises agricultural and forestry activities carried out in wetlands to conserve or maintain peatland ecosystems [7]. The activities practice planting with species that are adaptive to inundation, produce sufficient biomass in term of quality and quantity, and has no adverse effects on peat [8]. In principle, paludiculture uses local plant species that are adaptable to the natural conditions of the peat ecosystem [9].

The people of Tumbang Nusa Village mainly apply agroforestry systems, accounted for 68.75%. The remaining 31.25% apply monoculture of rubber, oil palm, balangeran, and pineapple. The majority of respondents (40%) applied monoculture of oil palm. The other 30% cultivated pineapple, 20% planted rubber, and 10% planted balangeran. The community were given capital assistance for oil palm plantations by the Regional Government of Pulang Pisau Regency. Meanwhile, respondents (Table 1) grew more pineapple and rubber for the polyculture system, combined with other crops (31.82% and 27.27%, respectively). Other respondents (40.91%) cultivated a combination of forest and annual crops.
Table 1. Planting pattern applied by respondents in Tumbang Nusa Village.

| No | Planting system                          | Number of respondents | Respondents in percentage |
|----|------------------------------------------|-----------------------|---------------------------|
| 1  | Monoculture                              | 10                    | 31.25                     |
|    | a. Palm oli                              | 4                     | 40.00                     |
|    | b. Pineapple                             | 3                     | 30.00                     |
|    | c. Rubber                                | 2                     | 20.00                     |
|    | d. Balangeran                            | 1                     | 10.00                     |
| 2  | Polyculture                              | 22                    | 68.75                     |
|    | a. Pineapple                             | 7                     | 31.82                     |
|    | b. Rubber                                | 6                     | 27.27                     |
|    | c. Forest plants combination             | 2                     | 9.09                      |
|    | d. Combination of forest and annual plants | 3                          | 13.64                     |
|    | e. Combination of annual and seasonal plants | 1                          | 4.55                      |
|    | f. Combination of annual plants          | 3                     | 13.64                     |

There are six cultivation patterns applied by the community in Tumbang Nusa Village, namely:

1. Pineapple-based with forest plants, fruits, and seasonal crops (31.82%)
2. Rubber-based with forest plants, fruits and seasonal crops (27.27%)
3. Combination of forest plants, including jelutung, gelam, balangeran, sengon, etc. (9.09%)
4. Combination of forest plants with annual crops, including jelutung, gelam, balangeran, sengon with petai, rubber, jengkol, rambutan, etc. (13.64%)
5. Combination of forest plants with seasonal crops, including jelutung, gelam, balangeran, sengon with chili, vegetables, tomatoes, cassava, and others (4.55%)
6. Combination of annual crops, including petai, jengkol, rambutan, mango, and others (13.64%)

Of the six techniques, the most applied pattern is pineapple-based (31.82%), a combination of pineapple and fruit crops (rambutan, jengkol, petai). The second is a pineapple-based pattern with forest plants (sengon, gaharu). The next is pineapple with annual plants (rubber).

The agricultural activities is generally carried out without draining (73%) or partially draining (27%). The land ownership is demarked by a small ditch of 40 cm in width and deep. To reduce waterlogging, especially during the rainy season, the soil mound is applied to elevate the ground level by burying soil to grow plants. This technique can reduce the soil wetness that accelerate rotting of roots. The drained lands are generally located adjacent to large canals at about 2 m and used to plant crops such as horticulture or oil palm, which are intolerant to waterlogging.

Agroforestry is a popular farming system. Besides, Silvofishery and Silvopasture are optional for farming activities. The land in Tumbang Nusa Village is dominantly characterized by deep peat, and some of them are shallow or medium peat. The land is utilized for semi paludiculture which combines native and introduced plants, simple management, and without canals and trenches for irrigation. Some of community members implemented pure paludiculture by growing native plants such as geam, balangeran, jelutung, pulai, rattan, purun, and ferns.

According to the community, cultivated plants are adaptive to peatlands and economically valuable. Some of the plants have high utilization value (UV) including Yellow Meranti (Shorea Balangeran) (0.41), Rubber (Hevea brasiliensis) (0.35), Jelutung (Dyera Lowii) (0.35), Nanas (Ananas comus) (0.35), Horticultura / Vegetables (0.32), Rambutan (Nephelium Lappaceum) (0.29),
Mango (*Mangifera Indica*) (0.26), Sengon (*Falcataaria Moluccana*) (0.24), Gelam (*Malaleuca Leucadendra*) (0.21), Palm Oil (*Elaeis Guineensis*) (0.18), and rattan (*Calamus sp*) (0.18).

A high UV indicates highly cultivated by the community [10]. In addition, it also indicates the abundance of plants [10], widely distributed on the land in Tumbang Nusa Village. However, the high use must be accompanied by conservation for these plants [11]. On the contrary, plants with low UV are little known by the community, difficult to obtain [10], or less economically valuable. Hence, these conditions cause the low level of use by communities.

The description of farming management carried by the community are as follows:

1) **Pure paludiculture**, some native species such as gelam, yellow meranti/balangeran, jelutung, pulai, purun, rattan and fern are found in peatlands. In this scheme, the land is in its original condition, and no cultivation being implemented. Management activities is harvesting timber and non-timber forest products such as gelam wood to be sold for construction, yellow meranti / balangeran, jelutung and pulai as a source of seeds for nursery, purun, and rattan for craft, and ferns as a source of vegetables for own consumption (Figure 1).

![Figure 1. Pure paludiculture. Paludiculture with native species in peatland (gelam, meranti yellow /balangeran, jelutung, pulai, purun, rattan, and ferns).](image)

2) **Aisle/Lane pattern (agroforestry)**, forest plants such as yellow meranti / balangeran, jelutung, pulai, rambutan, mango, are combined with native crops, like pineapple. In this form (semi-paludiculture intensive pattern), worm trenches as border lines of land ownership are formed by making soil mound and planted with native peat plants (balangeran, jelutung, pulai) and introduced plants such as sengon, or fruits such as rambutan or mango. The common spacing is 3x3 m (Figure 2).
Figure 2. Aisle/lane pattern (agroforestry), with a combination of yellow meranti/balangeran, jelutung, pulai, rambutan, mango, and pineapple.

3) **Mixed forest aisle/lane (agroforestry)**, this pattern combine native peat species with introduced and fruits plants including yellow meranti/balangeran, jelutung, pulai, sengon, rambutan, and mango. In this pattern (semi-paludiculture intensive pattern), soil mound was used as land border and planted with native peat plants (Balangeran, Jelutung, Pulai), introduced plant (sengon) or fruits such as rambutan or mango. The common spacing is 3x3 m (Figure 3).
Figure 3. Mixed forest aisle/lane pattern (agroforestry), with a combination of yellow meranti/balangeran, jelutung, pulai, sengon, rambutan, and mango.

4) **Mixed farm (agro-silvopasture).** This system combines native peat species, introduced plants (horticulture) and poultry. In this pattern (semi-paludiculture intensive pattern), soil mound was built as land border and planted with native peat plants (balangeran, jelutung, pulai), introduced plants (palm oil), and interspersed with horticulture/vegetables such as long beans and eggplant. The area between plants was used for duck cattle (Figure 4).
Figure 4. Mixed farm pattern (agroforestry dan silvopasture), with combination of yellow meranti/balangeran, jelutung, pulai, oil palm, horticulture/vegetables, and duck cattle.

5) **Mixed rubber farm (agro-silvopasture).** This pattern combines native plants, rubber and chicken livestock. It is considered as semi-paludiculture intensive pattern, by bordering community land with worm trenches to separate lanes for native peat plants (balangeran, jelutung, pulai) and introduced plants (rubber). The unplanted area is used for chicken livestock (Figure 5).

6) Mixed palm plantation (agro-silvofishery). This pattern brings together yellow meranti / balangeran, jelutung, pulai, palm, mango, rambutan, pineapple, and fish farming. This is a semi-paludiculture intensive pattern, by constructing a soil mound to border each plant. Native species of peatland (Belangeran, Jelutung, Pulai) were cultivated along with introduced plants (Palm Oil), and interspersed with fruits such as rambutan, mango, and pineapple. Ponds were built to cultivate pepuyu fish (Figure 6).

7) Mixed-pineapple was cultivated in combination with several native peatland species. Soil mounds were built to border land and planted with pineapple. Native species, such as Balangeran, Jelutung, Pulai, are planted randomly between the pineapple lane (Figure 7).
Figure 5. Mixed rubber farm model (agroforestry and silvopasture), with combination of yellow meranti/balangeran, jelutung, pulai, rubber, and chicken livestock.

Figure 6. Palm oil mixed model (agroforestry and silvofishery), with a combination of yellow meranti/balangeran, jelutung, pulai, oil palm, mango, rambutan, pineapple, and fish cattle.
Figure 7. Mixed pineapple farm pattern, with combination of pineapple and native species.

The seven patterns based on local wisdom are proven suitable for peatlands management. They are in accordance with modern peat management and are classified as pure paludiculture and intensive semi-paludiculture. These patterns are proven to minimize the occurrence of land fires commonly taking place in the dry season by maintaining soil moisture. The implementation of sustainable peatland management can maintain peatland similar to the original conditions, while adaptive cultivation systems do not require excessive efforts since involving native species that morphologically and physiologically are fit with the environment. Therefore, although peat soil are normally acidic and inundated, without draining the peatland, the risk of fire in the dry season can be minimized [12].

To increase the economic value of cultivation activities, it is necessary to implement paludiculture (native in peatland). Gelam is considered potential species for applying paludiculture. At the moment Gelam wood is mainly for building material.

Gelam leaves contain essential oils. The essential oil substance at 0.11% contains 1.4 sinesol compounds (1-isopropyl-4-methyl-7oxabicycli [2.2.1] hepttanes) as anti-fungal [13,14]. Gelam plants are medicinal herbs, especially as anti-bacterial [15], anti-inflammation, and antiseptic [16], and are traditionally used for diarrhea, skin diseases, cholera, intestinal worms, and muscle pain. In addition, Gelam leaves also have the potential as animal feed [17]. Improving the knowledge of gelam leaves refining is necessary to the community of Tumbang Nusa Village, to reduce logging while improving economic benefits from this plants. Hence, the knowledge transfer may conserve gelam wood stands as well as peatland ecosystems apart from the economic benefits for the community.
4. Conclusion

Several conclusions for the peatland management model applied at a moderate to deep peatlands by the community in Tumbang Nusa Village are as follow:

1. Agroforestry systems were commonly implemented by Tumbang Nusa Village community, interspersed forest with introduced plants. This can be seen from the presence of six cultivation patterns including pineapple-based with forest plants, fruits, and seasonal crops; rubber-based with forest plants, fruit, and seasonal crops; a combination of forest plants, including Jelutung, Gelam, Balangeran, Sengon, etc; a combination of forest plants and annual plants, including Jelutung, Gelam, Balangeran, Sengon with Petai, Rubber, Jengkol, Rambutan, and others; a combination of forest plants and seasonal crops like Jelutung, Gelam, Balangeran, Sengon with chili, vegetables, tomatoes, cassava, etc; a combination of annual crops, including Petai, Jengkol, Rambutan, Mango, and others.

2. Sustainable peatland management applied by the community of Tumbang Nusa village are pure paludiculture and semi-paludiculture intensive patterns that are formed into seven patterns suitable with the local conditions, namely pure paludiculture/original pattern, aisle/lane pattern, mixed forest aisle/lane pattern, mixed farm pattern, mixed-rubber farm pattern, mixed palm oil pattern, and mixed pineapple farm pattern.

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