Characteristics of peatland chemicals and their association with the diversity of dominant plants in Papua

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Abstract. Peatlands are often associated with an area that has a specific habitat in a particular area. The purpose of this study was to determine the characteristics and associations of the dominant biodiversity in the Mappi Regency, Papua. The research method used was a survey. The survey was conducted in Bamgi District, Mappi, Papua. The results showed that peat soils in Mappi have characteristics that are categorized as fabric-peat. Acidity or soil pH condition belongs in the low category (3.95-4.53), moderate C-organic (16.31%), high nitrogen (1.09%), moderate C/N ratio (15.01), whereas soil texture was from clay loam to sandy silt loam. This peatland is associated with various types of important tree groups flora, such as sago, agarwood, or gaharu (Aquilaria spp), massoy tree, rubber, and whitebark tree or gambir. Based on the level of importance, this peatland area contains various important plant species. Thus it needs to be conserved with appropriate area management.

1. Introduction

Peatland is an area that is naturally often waterlogged and in the form of swamps, so it is often referred to as peat swamps. Peat swamp is one of the natural resources with hydrological and environmental functions that are important for the life and survival of humans and other organisms [1,2]. Thus, the important existence of peat swamp areas must be followed by protection activities and their preservation.

To wisely utilize the natural resources in peat swamp requires careful planning, application of appropriate technology, and proper management. The three main issues will relate to the quality and sustainability of natural resources and the environment so that they can be maintained to support sustainable development [2,3]. In order to carry out these steps, basic data are needed in the form of spatial data on peatlands, information on characteristics, biodiversity on peatlands, as well as local community interactions in the area and the environment around peatlands. The characteristics of peat and their associations in a particular area are very important to support the conservation of peatlands.

The area of peatlands in Indonesia is estimated to be around 13.5-26.5 million hectares. At least 11 million hectares exist based on varied data sources. According to Driessen [4] in Indonesia, 17 million hectares of peatlands stretches from the east coast of East Sumatra with 9.7 million hectares covering the provinces of Riau, Jambi and South Sumatra. 6.3 million hectares in Kalimantan cover West Kalimantan and Central Kalimantan, and in Papua, there are indications of 100,000 hectares of...
peatlands. Meanwhile, according to Wahyunto et al. [3], peat swamp is mostly found on four large islands, namely Sumatra 35%, Kalimantan 32%, Sulawesi 3% and Papua 30%. When referring to Driessen [4], it is estimated that 30% of the peatland area in Papua reaches 5.1 million hectares.

Peat swampland is a type of swamp forest that is a specific and fragile ecosystem. Peat ecosystem degradation is caused by several factors, including changes in land use, deforestation, illegal logging, forest fires, and others. For this reason, peatland management needs to be done wisely and carefully. If the management system is not carried out properly, the forest ecosystem will not be sustainable. The type of vegetation that grows in the peat swamp area is very specific and has high economic value both from its timber and non-timber products such as sap, rattan, medicinal plants, agarwood (*gaharu*), etc. Some types of high commercial wood such as *jelutong* or Swamp Jelutong (*Dyera lowii*), *nyatoh* (*Palaquium spp*), *bintangur*, or Oil-nut Tree (*Calophyllum spp*), etc.

Peatlands have important functions in maintaining and regulating the ongoing process of the environment, such as water reservoirs, carbon sink and deposit, biodiversity, and other needs for human welfare. Peat swamp forests that have been degraded both as a result of illegal logging, looting, and forest fires and others must immediately be rehabilitated to restore ecological functions and increase productivity so that the ecosystem functions can be restored soon. One of the rehabilitation activities of peatlands that have been damaged is through revegetation. The proper revegetation is by replanting native species plants.

The wise and sustainable management of peat swamp forests is one of the best steps that need to be taken. Information on the existence of peat swamps in Papua to date has been inaccurate, both in terms of location, type of area, and biodiversity in the existing peat swamp area, while the potential damage to existing peatlands is increasingly apparent with the incessant investment as plantation development in Papua Province. While, the attention from the government, researchers, and the public so far on the existence of the Papua peat swamp are still very minimal. For this reason, it is hoped that this research will be useful as a first step in supporting the sustainable management of peatlands in Papua.

2. Methods

2.1. Research location and time
The research was carried out in the peat swamp forest area in Bamgi District, Mappi Regency, Papua Province (Figure 1). The survey was conducted from June to November 2018. A sampling of peat soils was carried out in the Bangge River watershed and surrounding peat swamp systems.

2.2. Peatlands survey and identification of flora fauna association
The peatlands survey was carried out by visually observing and analyzing the soil in a laboratory. The characteristics of peat are observed by taking soil samples and doing laboratory analysis. Soil sampling is done with the help of a drilling tool.

The survey on the existence of flora in the peatlands area was carried out by the cruising method. This method is used to find out the diversity of flora species found in a large area of peatlands.

2.3. Data analysis
The research data were analyzed qualitatively and quantitatively, based on the results of the analysis in both the field and laboratory. Peat soil samples were analyzed at the *Balai Penelitian dan Teknologi Pertanian* (Agricultural Research and Technology Center), Yogyakarta.
3. Results and discussion

3.1. Peatlands characteristics

The results showed that in Mappi Regency, especially in Yeloba Village in Bamgi District, Peatlands were found. Physically, the dark brown river empties into the Digoel River. Nearing the upstream, it appears that the color of the water is getting murkier. The fact is that the area around the river shows that the swamp area contains blackish-brown water.

Observations show that this swamp area is a swamp with a larger coverage area, and the water is dark brown. Bangge River is one of the accesses to the Yeloba Village in the Bamgi District. This river is affected by the tidal currents of the ocean.

In some soil sampling locations, drilling was carried out at a depth of 80 cm, while in other parts, it reached 320 cm. The level of peat thickness is estimated to range between 10-60 cm. In this area, which is a swampy lowland, the possibility of the influence of tides still exists. High rainfall also affects the tides in the region.
Table 1. Characteristics of peat soils in Bamgi District, Mappi, Papua.

| Physicochemical characteristics of peat soils | Soil sample | Avg |
|---------------------------------------------|-------------|-----|
| pH (H₂O)                                    | 4.53        |     |
| pH (KCl)                                    | 3.57        | 3.65|
| Organic C (%)                               | 13.94       |     |
| N total (%)                                 | 0.91        | 1.09|
| Ratio C/N                                   | 15.29       | 15.01|
| P available (ppm)                           | 15          | 10.00|
| K-dd (cmol.kg⁻¹)                            | 0.35        | 0.44|
| Ca-dd (cmol.kg⁻¹)                           | 0.43        | 0.76|
| Na-dd (cmol.kg⁻¹)                           | 0.17        | 0.31|
| Mg-dd (cmol.kg⁻¹)                           | 0.71        | 1.09|
| CEC (cmol.kg⁻¹)                             | 16.24       | 22.86|
| Base Saturation (%)                         | 10.24       | 11.29|
| Al-HddKCl 1N:                                |             |     |
| Al-dd (me.100g⁻¹)                            | 2.48        | 2.20|
| H-dd (me.100g⁻¹)                            | 5.58        | 6.33|
| Soil Texture                                |             |     |
| Sand (%)                                    | 10          | 27.67|
| Silt (%)                                    | 63          | 44.33|
| Clay (%)                                    | 27          | 28.00|

The analysis results of soil samples showed that the degree of acidity (pH: H₂O) ranged from 3.95 to 4.53, with an average of 4.17 classified as extremely acidic. Organic C content is between 13.94-18.16%, with an average of 16.37% belongs to the high category. The total N content ranges from 0.91-1.27%, with an average of 1.09%, including the very high category. For the C/N ratio between 14.30-15.45 with an average of 15.01 (moderate).

The characteristics of peatlands usually have the acidity of very strongly acidic to extremely acidic. The analysis showed that the pH ranged from 3.95-4.53. According to Barchia [5], most peat soils have a pH <4.0. As a comparison, peat in Central Kalimantan has a pH ranging from 3.25 to 3.60. The C-organic content is also high ranging between 51.00-58.00 in Kalimantan, while in Yeloba village, it is only around 16.37%, which is much lower. The C/N ratio is also similar; only 15.01 (moderate) is much lower than in Kalimantan, which reaches 31-49. The high content of C is related to the carbon stock value in an area. According to Sorensen (1993) and Warren et al. (2017), the high carbon content in peatlands is one source of carbon stock in the environment [6,7].

The available P content ranges from 6-15 ppm, with an average of 10.0 ppm (very low - low). Meanwhile, the contents of K, Ca and Mg were respectively 0.44 (very high), 0.76 (low), and 1.09 cmol.kg⁻¹ (very high). The value of land cation exchange capacity (CEC) is between 16.24-30.49 with an average of 22.86 (moderate-high), with a percent base saturation (BS) of around 11.29%. Soil analysis results show that peat soil in this area has a texture from clay loam to sandy silt loam. Judging from these characteristics, peat soils in this area classified as fibric-peat soil.
Figure 2. “Bus” or paperbark wood (Melaleuca sp.) is one of the dominant plants in peat swamp areas in Papua.

CEC value is related to the percent base saturation (BS) value. BS value is closely related to the prediction of the ease of nutrients available to plants. This value is also associated with considerations in the agricultural system, for example, fertilization. BS value in this peatland area is low. According to Winarso [8], soils that have a low pH are usually dominated by acid cations; therefore, the BS value is low.

Table 2. Several types of natural flora found in the peatlands of the district of Bamgi, Papua.

| No | Common Name (Indonesia and English) | Scientific Name | Utilization              |
|----|------------------------------------|-----------------|--------------------------|
| 1  | Rumput Malela (Para/Malela Grass)  | Brachiaria mutica | Untapped                 |
| 2  | Rumput Pisau (Bunchy Sedge)      | Cyperus polystachyos | Untapped                 |
| 3  | Pandan Rawa (Swamp Pandan)       | Pandanus sp     | Handicrafts              |
| 4  | Keladi Rawa (Swamp Sedges)       | Cladium sp      | Wrapping leaves          |
| 5  | Pisang-Pisangan (Heliconia)      | Heliconia sp    | Decorative plants        |
| 6  | Rotan (Rattan)                   | Calamus sp      | Strap, traditional medicine |
| 7  | Teratai Kecil (Water Lillies)    | Nymphaea sp     | Decorative plants        |
| No. | Species Name                  | Scientific Name       | Utilization                  |
|-----|------------------------------|-----------------------|------------------------------|
| 8   | *Sagu* (Sago Palm)           | *Metroxylon sagu*     | Local’s staple               |
| 9   | *Bus* (Paperbark)            | *Melaleuca leucadendron* | Building material           |
| 10  | *Ketapang Hutan* (Tropical Almond Tree) | *Terminalia cattapa* | Building material           |
| 11  | *Gempol* (Yellow Cheesewood) | *Nauclea orientalis*  | Building, traditional medicine |
| 12  | *Mersawa* (Mersawa)          | *Anisoptera sp*       | Building material           |
| 13  | *Palem ekor ikan* (Fishtail Palm) | *Caryota mitis*      | Decorative plants           |
| 14  | *Kayu Sasa* (Blackboard Tree) | *Alstonia scholaris* | Building, traditional medicine |
| 15  | *Resak* (Vatica)             | *Vatica sp*           | Building material           |
| 16  | *Mangrove* (Mangrove Tree)   | *Avicenia sp*         | Building material           |
| 17  | *Baringtonia* (Powderpuff Tree) | *Baringtonia racemosa* | Building material           |
| 18  | *Beringin* (Fig Trees)       | *Ficus sp*            | Building material           |
| 19  | *Kayu besi (merbau)* (Borneo/Malacca teak/ Moluccan ironwood) | *Intsia palebanica* | Building material           |
| 20  | *Dayung* (Kingiodendron)     | *Kingiodendron setarnifolium* | Boats, Oar |
| 21  | *Jambu-Jambuan* (Brush Cherry/ Water Apple) | *Zyigium sp* | Building material           |
| 22  | *Mangga Hutan* (Forest Mango) | *Mangifera sp*       | Building material           |
| 23  | *Gambir* (Whitebark)         | *Endiandra fulva*     | Medicinal                   |
| 24  | *Pohon Karet* (Rubber Tree)  | *Havea brasiliensi*   | Saps/latex                  |
| 25  | *Paku Larat* (Giant Swordfern) | *Nephrolepis biserrata* | Ferns                       |
| 26  | *Teki Air* (Coco-grass)      | *Cyperus sp*          | Untapped                    |
| 27  | *Rumput Bebek* (Jungle Grass) | *Echionochloa colona* | Untapped                    |
| 28  | *Liana* (Tiger’s Claw)       | *Deris sp*            | Not utilized                |
| 29  | *Paku Lemidi* (Diliman Fern) | *Stenochlaena palustris* | Not utilized |
| 30  | *Putri Malu* (Shy Plant)      | *Mimosa pudica*       | Not utilized, as medicines in other regions |
| 31  | *Kayu lawing* (Kulilawang)   | *Cinnamomum culillawan* | Building material           |
| 32  | *Kayu masohi* (Massoy bark)  | *Cryptocarya amassoy* | Traditional Medicine, Export Value |
A high CEC value is associated with high clay content. This condition appears in the results of soil analysis, which shows the texture of clay loam to sandy silt. In addition, the high value of CEC also indicates the possibility of high organic content, the high ability to absorb nutrients, and the high soil ability to retain water [8]. In addition, high CEC can be used to predict the possibility of land use for agriculture. If so, land like this requires a lot of lime to adjust the normal pH, the application of fertilizer can be in higher doses so that the frequency is rare.

3.2. Dominant plants in Peatlands
The observations showed that in the peatland area of the Bamgi District, Mappi Regency was known to be dominated by sedges (Cyperus spp.), Malela grass (Brachiaria mutica) (Cyperaceae), and bunchy sedges (Carex sp). For the group of trees dominated by “bus” or paperbark tree (Melaleuca leucadendron) (Figure 2), acacia (Acacia auricularia), pandan (Pandanus sp.), blackboard tree (Alstonia scholaris). Important plants with economic value are also found in this region, including agarwood (Aquilaria sp.), Massoy bark (Cryptocarya amassoy), whitebark (Endiandra fulva), and rubber (Hevea brasiliensis).

Sago plant (Metroxylon sago) is one of the important plant species found in this region (Table 2). According to Mubeki [9], sago (Metroxylon sago) was found to grow predominantly in low-lying areas in swamp habitat. This plant has an important value because it is used by local people as a staple food.

In addition, plants of the family group Poaceae (grasses), Araceae (tubers), Arecaceae (palm and rattan) are also found in this region. Poaceae plant group dominates the open area to form large grasslands. Arecaceae group plants are often found in wet habitats, but not waterlogged, while the Arecaceae group dominates rather than dry land.

In many cases, expanses of grassland plants and sedges (Cyperaceae) are able to grow in conditions of waterlogged soil habitats. In fact, the depth of the water can reach 3 meters, so this plant seems to float. Under these conditions, local people often refer to it as “rumput goyang” (rocking grass).

3.3. The importance of peatland ecosystem value for the people
Peatlands have high economic and ecological value. Based on various studies, peat areas play a role as a source of livelihood for local communities [10], as habitats for various types of flora and fauna [2,11–13] and as carbon stocks [6][7].

In the peatlands in the Bamgi District, it appears that this swamp area has several types of plants with high economic value. One of the dominant ones is sago (Metroxylon sago), agarwood (Aquilaria spp), Massoy barks, rubber, and Whitebark tree or “Bus” wood (Melaleuca spp) is one of the plant

| No. | Plant Name                  | Scientific Name          | Economic Value                              |
|-----|----------------------------|--------------------------|---------------------------------------------|
| 33  | Kayu gaharu (Agar Wood)    | Aquilaria spp.           | Medicine, Agarwood, Export Value            |
| 34  | Ketapang (Cattapa)         | Terminalia canaliculata  | Building material                            |
| 35  | Macaranga (Macaranga Tree) | Macaranga sp.            | Firewood and building materials             |
| 36  | Pala hutan (Wild Myristica)| Myristica sp.            | Fruits, building material                    |
| 37  | Rumput pisau (True Sedge)  | Carex sp.                | Handicrafts                                  |
| 38  | Simpur (Dillenia)          | Dillenia sp.             | Building material                            |
| 39  | Akasia (Acacia)            | Accasia auricularia      | Building material                            |
| 40  | Palem (Palm)               | Licula sp.               | Decorative plants                           |
species that is used as the main building material, both for housing and other needs such as bridges. The potential of agarwood in Papua is very high. It is estimated that the largest agarwood population is in the districts of Asmat and Mappi. In addition, according to Mubeki [9], the lowlands of Papua are known as the biggest producers of sago in Indonesia. According to public information, the potential of Whitebark and Massoy plants is also promising, although the problem of unstable prices and marketing is still an obstacle.

Rapid population growth causes quite large needs for development land. This condition will threaten the existence of peatlands. According to Hansen et al. [14], the decline in the peatland area in Indonesia is quite high. The high decline is also related to the utilization of land for agricultural land development. According to Alwi & Hairani [15], the use of land for agriculture must be wise so that it is appropriate and does not damage the peatland area, which can harm various parties. Thus, in-depth studies are needed to utilize peatland areas for sustainable development.

4. Conclusions and suggestions

Peatlands in Mappi, especially in the Bamgi District is a group of fibric-peat. Analysis of soil samples showed low pH (3.95–4.53), moderate C-organic category (16.31%), high nitrogen (1.09%), moderate C/N ratio (15.01). This peatland is associated with various types of important flora in tree groups, such as sago (*Metroxylon sago*), agarwood (*Aquilaria spp*), massoy plants, rubber, and whitebark trees. This peatland area has not been well managed, it contains various types of important plants, so it needs to be conserved with appropriate management. An in-depth study is needed to find out the proper utilization in the development of strategic lowland areas in Papua.
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