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Biomass and Soil Nutrients Turnover Affected by Different Peat Vegetation

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ABSTRACT

This research aimed at analyzing potential supplies and removals of biomass and soil nutrients induced by different vegetation on peatlands. The research was carried out in a peat dome at the catchment area of the Sibumbung River and the Burnai River in Pedamaran Sub-Districts, Ogan Komering Ilir (OKI) South Sumatra. The research method used field survey of case studies of four natural phenomena (swamp grass, bush swamp, cultivated peatlands, and peat forest). The research resulted that the highest production and harvest of biomass came from peat forest, cultivated peatlands, bush swamp and swamp grass. The highest biomass supply to the soils were given by the peat forest, cultivated peatlands, bush swamp and swamp grass (around 12,545; 11,593; 7,491 and 5,313 kg/ha/year respectively). The more varied the vegetation type, the higher the supply of soil nutrients. Swamp grass and bush swamp have low vegetation diversity and are mostly dominated by *alang-alang*. Swamp grass and bush swamp showed the same pattern and the order of nutrient supply in the highest sequence is K, Ca, N, Mg, Ca, and P. The supply order of soil nutrients (peat forest and cultivated peatlands) showed a similar pattern, namely from the highest content of Ca, N, K, Mg and P. Pulai vegetation can be recommended for a paludiculture system because it resembles almost the peat forest in producing biomass and soil nutrient supply to the soils and is originally native plant from peatland.

Keywords: Decomposition eutrophication, soil nutrient, peat vegetation

INTRODUCTION

Conversion of tropical peatlands showed a positive impact on increasing agriculture production, but had a negative impact on peatland resources globally (*Armanto*, 2019a; 2019b). Thus, research theme of the land clearing impact on changes in ecological, physical, and chemical properties is widely conducted (*Audet et al.,* 2020; Abdel Rahman *et al.,* 2020). Researchers reported that there has been a reduction in ecological productivity and negative impacts on the environment due to the conversion of peatlands into agricultural land (*Barchia et al.*, 2021; El Falah *et al.*, 2021; Juottonen, 2020). After several years of planting, soil properties changes depending on the type of land use, tillage, type of peat, physiography and soil parent material (*Hinzke et al.*, 2021a; 2021b; *Junedi et al.*, 2017). Very few researchers have succeeded in uncovering the types of land use that can reduce land productivity and often conclusions from studies are contradictory, especially those carried out in South America and Africa (Moore *et al.*, 2019; *Negassa et al.*, 2019).

In natural peat ecosystems, the relationship between soil, vegetation, plants, nutrients and water is a natural dynamic (*Michaelis et al.*, 2020; Lin *et al.*, 2020). Vegetation and plants absorb nutrients and water from the soils for metabolic processes. Vegetation and plants provide input of biomass through litter that is buried on the ground in the form of fallen leaves, twigs and branches as well as rotting wood. The roots of vegetation or plants provide input of organic matter through the root system and dead root caps and from root exudation. Organic matter present on the soil surface and organic matter in the soil will undergo decomposition and mineralization and release available nutrients

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into the soil. This nutrient cycle process is defined as the supply of nutrients continuously (continuously). This continuous supply of nutrients also involves input from the result of weathering of soil minerals, biota activity, and other transformations in the biosphere, lithosphere and hydrosphere (*Zuhdi et al.*, 2019).

The natural peat forest ecosystems is considered as closed nutrient cycle because this system shows a lower amount of nutrient loss compared to the amount of nutrient input obtained from the decomposition of litter or from the re-absorption of nutrients in the soil layer (high efficiency of nutrient use). Meanwhile, the agricultural system has a high nutrient cycle 'open' because it has a large amount of nutrient loss (*Wildayana and Armanto*, 2018a; 2018b; 2018c).

Nutrients supply induced by different vegetation can be done by analyzing cultivated plants or vegetation, comprehensive soil profiles and laboratory analysis (*Yan et al.*, 2019). The analysis can be an approximation to the general picture of the troop potential, removal of soil biomass and nutrients by different vegetation on peatlands (*Yu et al.*, 2019). Thus, it can explain why for the same type of peatlands and parent material, but the productivity for cultivated plants, especially in South Sumatra, is different. Based on the above problems, this research aims to calculate and to analyze potential supply and removal of biomass and soil nutrients induced by different vegetation on peatlands. The results of this research are expected to provide basic information about the potential of nutrient reserves on soil productivity.

MATERIAL AND METHODS

The research was carried out in a peat dome at the catchment area of the Sibumbung River and the Burnai River in Pedamaran Sub-Districts, OKI South Sumatra, Indonesia. According to Minister of Environment Decree No.Sk.129/Menlhk/Setjen/Pkl.0/2/2017 concerning determination of the KHG map, the research site belongs to “Peat Hydrological Unit (KHG) Sungai Burnai river - Sibumbung river covering an area of 86,679 ha”.

The research method used field su9rvey of case studies of four natural phenomena, namely swamp grass, bush swamp, cultivated peatlands, and peat forest (Figure 1). The character of the complete physical and chemical analysis of the soil was carried out by taking composite soil samples after a description of the soil profile was carried out for later analysis. Biomass of plants and vegetation were recorded using a 10 m x 10 m square field and then combined with the results of questionnaires and farmer interviews.

A (swamp grass) B (bush swamp) C (cultivated peatlands) D (peat forest)

Figure 1. The research site for sampling

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RESULTS AND DISCUSSION

The results and discussion are focused only on six main components, namely general description of sampling research area; total biomass produced by vegetation and plant residues; soil nutrients and biomass removal due to harvest; supply of total biomass from vegetation and plant residues; and potential supply of soil nutrients from vegetation and plant residues.

General Description of the Research Sampling Area

The climate of the research site belongs to the wet-climate because they are accumulated in the areas with type B rainfall (7-9 wet months). On average rainfall was around more than > 2,200 mm/year with uneven rainfall distribution throughout the year. All research sites include the category plains physiographic group; altitude ranges from 0-2 m above sea level and peat thickness is in the range 1.0-6.5 m. General description of sampling area in the research area (Table 1).

a. Sampling Site A (Swamp Grass)

Swamp grass consist of a mixture of natural vegetation and grasses, dominated by alang-alang (*Imperata cylindrica* L.), seduduk (*Melastoma* Sp), *Zalaca* spp, *Pandanus* spp, *Crunis* spp, vines and creepers among *Uncaria* spp, including occasionally and others, age less than 2 years. Swamp grass has a very low to low fertility rate and shows an intensity of leaching process because the raw grass is burnt 1-2 times/year or more. Thus, peat degradation cannot be contained, especially rain energy and rainwater causing an intensive decrease in soil fertility including forest and land fires. Furthermore, the main composition of *alang-alang* is dominated by Si (2.66%) and micro nutrients Mn (98.72 ppm), Zn (8.99 ppm) and Cu (6.29 ppm), but N, P, K very low. This causes swamp grass to be unable to increase peat productivity; The reeds are especially wasteful in the absorption of nutrients and water.

b. Sampling Site B (Swamp Bush)

Generally the canopy layer of swamp bush was dominated by mixture types of shrubs, purun tikus *(Eleocharis dulcis* Hensch), gelam (*Melaleuca cajuputi* Powell), nipah (*Nypafruticans sp),* ferns (*Polypodiopsida* or *Polypodiophyta* spp), medang *(Litsea spp),* kemuning *(Xantophyllum spp),* pelawan *(Tristania sp),* kayu malam *(Diospyroy spp),* jambu-jambuan *(Eugenia sp),* mendarahan *(Myristica spp)* and any others aged around 2-5 years, and small trees with a height of less < 2.5 m. Swamp bushes generally located in peat domes were previously cultivated by local farmers for farming *sonor system* such as rice, cereals and various vegetables. After sonor system was cultivated, the peatlands were left for fallow 5-10 years (no *sonor* system) and neglected until it is overgrown by swamp bushes.

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ISSN: 2477-5223 (Online)

Table 1. General description of sampling area in the research area

General characters	A swamp grass	B bush swamp	C cultivated peatlands	D peat forest
Position	104°57'18.58" E 3°26'37.31" S	104°53'35.12" E 3°25'53.37" S	104°57'52.37" E 3°25'22.83" S	104°57'54.64" E 3°25'20.42" S
Condition	Uncultivated, disturbed and drained	Uncultivated, disturbed and drained	Cultivated, disturbed and undrained	Uncultivated, undisturbed, undrained
Burning	1-2 times/year	1-2 times/year	Not burnt	Not burnt
Height (m)	0.5-1.0	1.0-2.5	3.0-6.0	5.0-10.0
Dominant vegetation	Purun tikus, *alang-alang*, pandanus spp, seduduk	Gelam, medang, kemuning, pelawan, kayu malam, jambu-jambuan, mendarahan	Planted with pulai, acacia, shrubs, grasses	Ramin, meranti, jelutung, acacia, nyatoh, kempas, mentibu, local rubber, pelawan, medang
Utilities	webbing materials, *sonor* system, animal feed, pens, pads	*sonor* system, animal feed, livestock barns, wood, hedges, firewood	wood, firewood, shrubs, grasses	harvested wood, firewood, shrubs, grasses
Age (years)	Less 2	2-5	5-15	15-20
Peat depth (m)	1-3	1-3	2-3	3-6
Mean of groundwater level (cm)	-45	-50	-65	-70

c. Sampling Site C (Cultivated Peatlands)

Sampling site C was planted with pulai (*Alstonia scholaris L.R.Br.),* combined with other natural peat vegetation and cultivated in order to restore peatlands. Pulai is called also (in local name; namely *kayu pule, kayu gabus, lame, lamo and jelutung*). The wood quality is not too hard and is not favored for building materials because the wood is easy to bend when damp, but is widely used to make wooden household utensils and carvings and sculptures. This tree is widely used for reforestation because the leaves are shiny green, lush and wide to the side so that it provides coolness. The skin is used for medicinal raw materials and efficacious for treating strep throat and others. Cultivated peatlands are found in peat dome with age of 5-15 years. Cultivated peatlands showed low leaching process because cultivated peatlands was not burnt anymore since replanting. Therefore, an intensive increase of soil fertility in cultivated peatlands were determined because of low peat degradation It mean that Cultivated peatlands are able to withstand peat degradation process (especially from rain energy and drainage water).

d. Sampling Site D (Peat Forest)

In the past, peat forests were selectively logged, so they could be classified as disturbed and not drained forests. Illegal logging is still happening and some is still ongoing, but the

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ISSN: 2477-5223 (Online)

amount of forest and wood that can be cut is limited. Most of the peat forest is included in the upper canopy layer formed by species, such as purun tikus (*Eleocharis dulcis* Hensch), jelutung (*Dyera lowii* L.), acacia (*Acacia* spp.), nipah (*Nypafruticans* sp), gelam (*Melaleuca cajuputi* Powell), ramin (*Gonystylus bancanus* L.), meranti merah (*Shorea balangeran*), sago (*Metroxylon* spp), tengkawang (*Shorea stenoptera*), gemor (*Alseodaphne* spp and *Nothaphoebe* spp); durian hutan (*Durio* sp), nyatoh (*Palaqium* spp), kempas (*Koompassia malaccensis*), banana (*Mezzetia parviflora* L.), mentibu (*Dactylocladus stenostachys* L.) and several types of natural vegetation that are generally less well known. Sporadic local rubber (*Hevea brassiliensis* L.). The age of peat forest (consisting some mixed trees, bush, and natural grass) was around 15-20 years old.

Total Biomass Produced by Vegetation and Plant Residues

Generally the highest biomass can be produced by the peat forest, cultivated peatlands, bush swamp and swamp grass (the lowest production of total biomass) with a number of sequential biomass supply of 25,275; 20,170; 15,040 and 9,985 kg dry biomass/ha/year respectively. Increasing biomass from the peat forest were dominantly derived from dried leaves, branches, twigs, wicker, decomposed wood and root litter which resides in the soils. In the swamp grass and bush swamp, most of biomass was dominantly derived from dried leaves, grass stalks, dried twig, wicker shrubs, roots and rhizome, and the supply of dried leaves of swamp grass was a little in amount (Table 2).

Soil Nutrients and Biomass Removal due to Harvest

Peatlands are known to have about 1,500 types of natural vegetation. It is estimated that around 30% of the total types of natural vegetation have direct benefits for human life, while the other 70% have indirect benefits for environmental services to support human life. They are harvested by local society, namely for food (including fruit, carbohydrate sources, protein, seasonings and fats/oils), high economic value wood, medicines (drugs), bio-energy (wood chips, charcoal, bio-ethanol), sap (latex); fiber (raw material for pulp and paper industry), and other by-products of the forest. Types of natural vegetation of peatlands on the basis of its benefits are presented in Table 3.

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Table 2. Total biomass and nutrients produced by vegetation and plant residues (kg/ha/year)

Research site	Biomass	N	P	K	Ca	Mg
A (Swamp grass)						
Dried leaves	2,115	3.60	2.75	11.84	7.40	5.92
Grass stalks, dried twig, wicker	3,120	9.36	1.56	17.47	10.92	1.87
Root litter and rhizome	4,750	16.63	8.08	18.05	9.03	9.50
Total	9,985	29.58	12.38	47.37	27.35	17.29
B (Bush swamp)						
Dried leaves	3,240	5.51	4.21	18.14	11.34	9.07
Dried twig, wicker, wood	5,100	15.30	2.55	28.56	17.85	3.06
Root litter	6,700	23.45	11.39	25.46	12.73	13.40
Total	15,040	44.26	18.15	72.16	41.92	25.53
C (Cultivated peatlands)						
Dried leaves	9,430	179.17	6.60	60.35	182.94	39.61
Dried twig, wicker, wood	8,173	25.34	2.45	3.27	59.66	4.90
Root litter	2,567	20.02	1.03	7.96	14.12	3.08
Total	20,170	224.53	10.08	71.58	256.72	47.59
D (Peat forest)						
Dried leaves	11,260	213.94	7.88	72.06	218.44	47.29
Dried twig, wicker, wood	11,250	34.88	3.38	4.50	82.13	6.75
Root litter	2,765	21.57	1.11	8.57	15.21	3.32
Total	25,275	270.38	12.36	85.14	315.78	57.36

The highest biomass removal come from peat forest, followed by cultivated peatlands, bush swamp and swamp grass is the lowest removal with a number of sequential supply of dry biomass 12,730; 8,577; 7,549; and 4,672 kg/ha/year respectively. The harvested biomass of peat forest consisted of wood, firewood, dried leaves, branches, twigs, roots, wicker, shrubs and grasses. However swamp grass biomass was mostly provided dried twig, wicker, wood, while the supply of dried leaves of swamp grass was very limited (Table 4). The harvest of biomass from cultivated peatlands consists of harvesting wood, firewood, shrub and grass. Almost every year, biomass of swamp grass and bush swamp was harvested in the form of animal feed, purun craft woven materials (mats, hats, souvenirs), firewood, cattle pens, cultivated hedges and others.

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Table 3. Types of natural vegetation of peatlands on the basis of its benefits

Direct benefits	Natural vegetation
Food (fruit, fats, oils, protein, carbohydrate, seasonings etc.).	Mangga kueni *(Mangifera odorata);* rambutan *(Nephelium spp);* asam kandis *(Garcinia xanthochymus);* nipah (*Nypafruticans sp);* mangga kasturi *(Mangifera casturi);* sago (*Metroxylon* spp); kerantungan *(Durio oxleyanus);* durian hutan; pepakan; pepaken *(Durio kutejensis);* tengkawang *(Shorea stenoptera*); kelakai *(Stenochlaena palustris)*
High economic value wood	Meranti merah *(Shorea balangeran)*; ramin *(Gonystylus bancanus)*; nipah (*Nypafruticans sp)*
Medicines/drugs	Pulai (*Alstonia scholaris);* akar kuning *(Coscinium fenestratum)*
Bio-energy (chips, charcoal, bio-ethanol)	Gelam *(Melaleuca cajuputi* Powell); sago *(Metroxylon* spp); nipah (*Nypafruticans sp)*
Sap (latex)	Jelutung *(Dyera lowii L.)*; local rubber (*Hevea brassiliensis* L.); nyatoh *(Palaqium spp);* sundi *(Payena sp., Madhuca spp)*
Fiber (pulp and paper industry)	Geronggang (*Cratoxylon arborescens* (Vahl.) Blume); acacia *(Acacia spp.);* terentang putih (*Campnosperma auriculatum*); gelam *(Melaleuca cajuputi* Powell)
Other forest by-products	Gaharu (*Aquilaria malaccensis);* purun tikus (*Eleocharis dulcis* Hensch); rotan iris (*Calamus trachycoleus*)

Table 4. Soil nutrients and biomass removal due to harvesting (kg/ha/year)

Research site	Biomass	N	P	K	Ca	Mg
A (Swamp grass)						
Dried leaves	1,115	1.90	1.45	6.24	3.90	3.12
Grass stalks, dried twig, wicker	2,120	6.36	1.06	11.87	7.42	1.27
Root litter and rhizome	1,437	5.03	2.44	5.46	2.73	2.87
Total	4,672	13.29	4.95	23.58	14.05	7.27
B (Bush swamp)						
Dried leaves	1,231	2.09	1.60	6.89	4.31	3.45
Dried twig, wicker, wood	3,618	10.85	1.81	20.26	12.66	2.17
Root litter	2,700	9.45	4.59	10.26	5.13	5.40
Total	7,549	22.40	8.00	37.41	22.10	11.02
C (Cultivated peatlands)						
Dried leaves	4,043	76.82	2.83	25.88	78.43	16.98
Dried twig, wicker, wood	3,170	9.83	0.95	1.27	23.14	1.90
Root litter	1,364	10.64	0.55	4.23	7.50	1.64
Total	8,577	97.28	4.33	31.37	109.08	20.52
D (Peat forest)						
Dried leaves	5,360	101.84	3.75	34.30	103.98	22.51
Dried twig, wicker, wood	5,620	17.42	1.69	2.25	41.03	3.37
Root litter	1,750	13.65	0.70	5.43	9.63	2.10
Total	12,730	132.91	6.14	41.98	154.64	27.98

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ISSN: 2477-5223 (Online)

Supply of Total Biomass from Vegetation and Plant Residues

The most dominant supply of biomass from peat forest is derived from dry leaves, branches, twigs, webbing, rotting wood and root litter in the soil. The addition of biomass from swamp grass mostly come from dry leaves, shrubs, roots and rhizomes. In general, the highest addition of biomass was peat forest, cultivated peatlands, bush swamp and grass swamp (its contributing is the lowest) with the order of biomass supply to the soil, namely 12,545; 11,593; 7,491; and 5,313 kg dry biomass/ha/year (Table 5). The high supply of biomass from peat forest is because peat forest does not burn anymore and produces a lot of biomass. On the hand, swamp grass is only able to add minimal biomass because it burns often and naturally grasses are not able to produce high biomass.

Table 5. Supply of total biomass from vegetation and plant residues (kg/ha/year)

General characters	A swamp grass	B bush swamp	C cultivated peatlands	D peat forest
Total dry biomass above the soils	9,985	15,040	20,170	25,275
Dry biomass harvested	4,672	7,549	8,577	12,730
Supply of dry biomass to the soils	5,313	7,491	11,593	12,545

Potential Supply of Soil Nutrients from Vegetation and Plant Residues

The nutrient supply capacity of plant residues and vegetation is dependent on the amount of plant residues and the type of vegetation itself. The results of this study indicate that peat forests are able to supply soil nutrients optimally and are followed by cultivated peatlands, swamp bushes and swamp grasses. The limited amount of biomass produced by swamp grass is because swamp grass is dominated by alang-alang (*Imperata cylindrica* L.), so that swamp grass is not able to provide nutrient supply to the soil. The canopy of the reeds is not able to cover the soil completely, this causes the soil surface to become the object of erosion and leaching processes. The absolute supply of soil nutrients per year from crop residues and vegetation is summarized in Table 6.

Based on the order of nutrient supply to the soil, peat forest and cultivated peatlands were able to provide the same supply of soil nutrients and were able to add the highest amounts of Ca, N, K, Mg and P. Swamp grass and swamp bushes are able to provide soil nutrient supply as well as the order of nutrient supply to the soil starting from the most capable of providing nutrients sequentially, namely K, Ca, N, Mg, Ca, and P. From the order of soil nutrient supply above, it is clear that vegetation diversity has an effect and plays a very important role in providing the order of soil nutrient supply. Swamp grass and bush swamps have low vegetation diversity and are mostly dominated by alang-alang (*Imperata cylindrica* L.), while peat forests and cultivated peatlands are natural vegetation and grow with other natural peat vegetation, thus the order of soil nutrient supply is Ca, N, K, Mg and P for peat forests and cultivated peatlands; and K, Ca, N, Mg, Ca, and P for swamp grass and bush swamp.

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Table 6. Supply of soil nutrients from vegetation and plant residues (kg/ha/year)

Research site	Biomass	N	P	K	Ca	Mg
			A (Swamp grass)			
Dried leaves	1,625	2.76	2.11	9.10	5.69	4.55
Grass stalks, dried twig, wicker, wicker, wood	2,151	6.45	1.08	12.05	7.53	1.29
Root litter and rhizome	1,537	5.38	2.61	5.84	2.92	3.07
Total	5,313	14.60	5.80	26.99	16.14	8.91
			B (Bush swamp)			
Dried leaves	1,431	2.43	1.86	8.01	5.01	4.01
Dried twig, wicker, wood	3,318	9.95	1.66	18.58	11.61	1.99
Root litter	2,742	9.60	4.66	10.42	5.21	5.48
Total	7,491	21.98	8.18	37.01	21.83	11.48
			C (Cultivated peatlands)			
Dried leaves	5,643	107.22	3.95	36.12	109.47	23.70
Dried twig, wicker, wood	4,270	13.24	1.28	1.71	31.17	2.56
Root litter	1,680	13.10	0.67	5.21	9.24	2.02
Total	11,593	133.56	5.90	43.03	149.89	28.28
			D (Peat forest)			
Dried leaves	5,345	101.56	3.74	34.21	103.69	22.45
Dried twig, wicker, wood	5,420	16.80	1.63	2.17	39.57	3.25
Root litter	1,780	13.88	0.71	5.52	9.79	2.14
Total	12,545	132.24	6.08	41.89	153.05	27.84

From the results and discussion of this research, it can be recommended that the pulai plant almost resembles the peat forest in producing biomass and soil nutrient supply to the soils because the pulai plant is originally native vegetation derived from peatland. Therefore, it can be concluded that the pulai plant can be used as a paludiculture plant which is highly recommended for restoring peatlands.

The minimum P supply from the four study sample areas (swamp grass; bush swamps; cultivated peatlands; and peat forests) indicated that P nutrient was the dominant limiting factor for the growth of each plant on peatlands. This is understandable because the main element of P nutrient comes from apatite rocks or the remains of life. Both are not found in forests and peatlands, so their P nutrient values are very minimal and critical. Therefore, if there are plants to be planted on peatlands, then the application of P fertilizer is essential for plants to produce optimal biomass.

CONCLUSSION

Based on the results and discussion of this research, some conclusions can be drawn as follows:

1) The highest production and harvest of biomass came from peat forest, cultivated peatlands, bush swamp and swamp grass.
2) The highest biomass supply to the soils were given by the peat forest, cultivated peatlands, bush swamp and swamp grass (around 12,545; 11,593; 7,491 and 5,313 kg/ha/year respectively).
3) The more varied the type of vegetation, the higher and more varied the supply of soil nutrients. Swamp grass and bush swamp have low vegetation diversity and are

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mostly dominated by *alang-alang* (*Imperata cylindrica* L.). Thus, swamp grass and bush swamp showed the same pattern and the order of nutrient supply in the highest sequence is K, Ca, N, Mg, Ca, and P. The order of supply of soil nutrients (peat forest and cultivated peatlands) showed also a similar pattern, namely from the highest content of Ca, N, K, Mg and P.

4) Pulai vegetation can be recommended for a paludiculture system because the pulai vegetation resembles almost the peat forest in producing biomass and soil nutrient supply to the soils. Pulai vegetation is originally native plant derived from peatland.
5) The minimum P supply from the four study sample areas indicated that P nutrient was the dominant limiting factor for the growth of each plant on peatlands.

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