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Plant species diversity and cluster analysis in difference logged-over peat swamp forests in Riau, Indonesia

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Abstract. Peat swamp forest is one of the wetland tropical rainforest ecosystems widespread in Indonesia. This study aimed to analyze plant species diversity of tree stage in difference logged-over peat swamp forests at PT. Diamond Raya Timber, Riau Province. This study site was divided into three different locations, newly logged-over peat forest swamp forest (NLPSF), three years logged-over peat swamp forest (3LPSF) and four years logged-over peat swamp forest (4LPSF). Primary species of tree stage in the study site were grouped into three parts, i.e., firstly, Dipterocarpaceae family mainly consists of meranti bunga (*Shorea teysmanniana*) and meranti batu (*S. uliginosa*), secondly, non-Dipterocarpaceae included balam (*Palaquium hexandrum*), milas (*Parastemon urophyllus*), macang (*Mangifera havilandii*), punak (*Tetramerista glabra*), jambu (*Eugenia* sp), pisang-pisang (*Mezzetia parviflora*), and arang-arang (*Gynotroches axillaries*), and thirdly, particular species of ramin (*Gonystylus bancanus*). The pattern of species grouping for tree level was more centered in the NLPSF compared to other sites. On the other hand, species diversity in tree level found more diverse in 4LPSF, suggested the various ecological parameters. Cluster analysis showed the occurrence of species relationship in the sites based on diameter and importance values indicated the presence of species similarity and habitat preference.

1. Introduction

Peat swamp forest is one of the wetland rainforest ecosystems that widespread in Indonesia [1]. As a typical ecosystem, peat swamp forests have essential flora and fauna characteristics for foreign exchange, germplasm sources, and surrounding ecosystem buffers [2]. The potential for swamp forests in Indonesia is still enormous. The swamp forest areas in Indonesia still exists about 32% of the forest concession area (*Hak Pengusahaan Hutan/*HPH) in flat and undulating areas that are not harvested or equivalent to an area of 6.2 million ha [1]. This forest can produce 30 m^3/ha of commercial logs by harvesting the selective logging system. The potential of this large swamp forest needs to be optimally and efficiently utilized by applying the appropriate silvicultural system.

Based on the Decree of the Director General of Forest Exploitation no. 564/Kpts /IV-BPHH/1989 on the Indonesian Selective Cutting and Replanting System (*Tebang Pilih Tanam Indonesia/*TPTI) silvicultural system used for peat swamp forest is TPTI with some exceptions. Given a modification of the system is generally used for dryland forests that characterize different ecosystems with peat swamp forests [3]. In the implementation of the silvicultural system, residual standing and tree regeneration damage are primarily consequences due to uncontrolled logging, including a limit of

non-compliant harvest diameter and use of small *Gonystilus bancanus* trees for the construction of lorry trails [3]. It is important therefore to evaluate the effect of selective cutting on species diversity, which may provide added information on the silvicultural system. The study of species pattern and distribution is useful in the understanding landscape, ecological process, and silvicultural system [4]. Clustering of species data is used to obtain such description and representation. Clustering vegetation data is well known to partition common traits that describe species habitat preference from field data [5]. With respect of clustering sites, it allows to differentiate between those species that characterize individual groups, and those explain the similarity between species [5-6]. The present study, therefore, was conducted to determine the diversity of tree species in difference peat swamp forests (newly, three years, and four years logged-over) in Riau Province, Indonesia.

2. Materials and method

This study was carried out in PT. Diamond Raya Timber, Riau Province, Indonesia. The Forest concession is situated at between 100°50'-101°13' East Longitudes (EL) and 001°45'- 002°18' North Latitudes (NL). Regionally, it is located at Rokan Hilir Regency and Dumai City, Riau Province, Indonesia (figure 1). This study site was divided into three different locations as shown in Figure 1. Three locations, namely newly logged-over peat swamp forest (NLPSF) was sited at 101°11'34'' ET and 001°36'29'' NL, three years logged-over peat swamp forest (3LPSF) was located at 101°09'23'' ET and 001°58'12'' NL, and four years logged-over peat swamp forest (4LPSF) at 101°06'17'' ET and 001°37'36'' NL was selected. In this study for the three logged-over peat swamp forests in the tree stage, measurement was carried out using a method of a lane with a size of 250 X 100 m with three replications which included measurement of species inventory, individual number, diameter, and height as previously described [7-8].
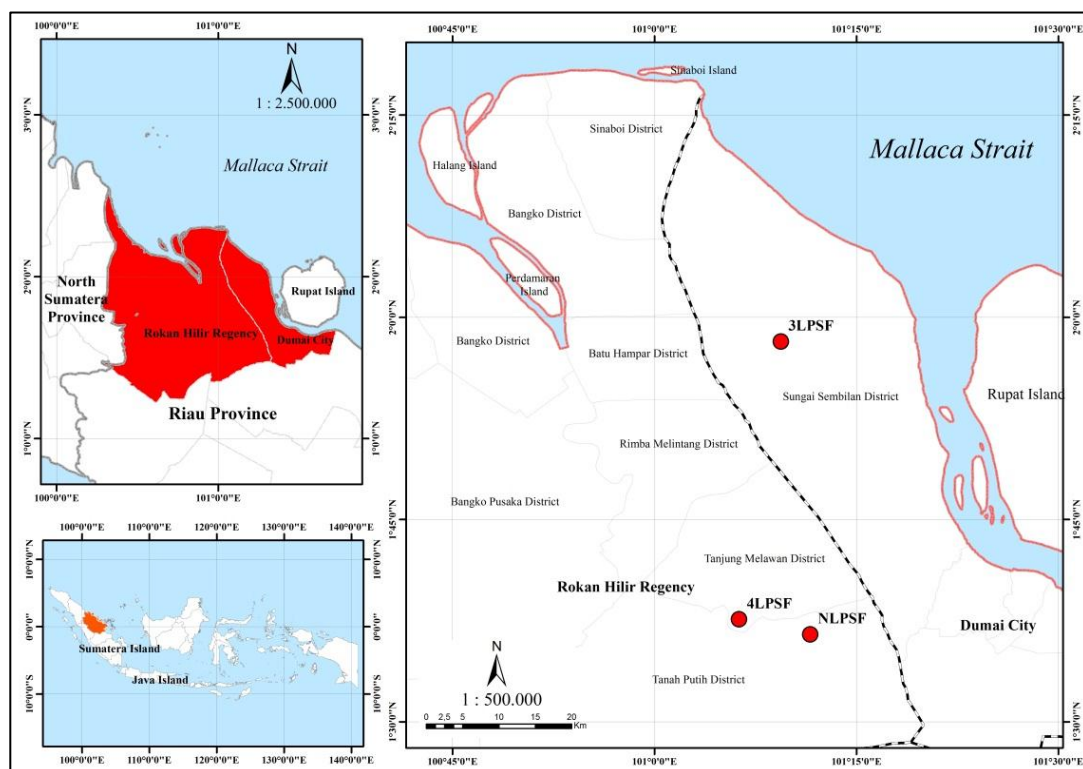

Figure 1. The location of study at PT. Diamond Raya Timber, Riau Province, Indonesia. NLPSF = Newly logged-over peat swamp forest, 3LPSF = three years logged-over peat swamp forest and 4LPSF = four years logged-over peat swamp forest.

Based on the Schmidt and Ferguson of climate classification, this study site belongs to type A with a value of Q = 10.1%. Annual rainfall was 2,358 mm, while the average monthly rainfall ranged from 51.32-301.6 mm/month, the highest rainfall falls in November (301.66 mm). The lowest rainfall falls in March (51.3 mm).

For diameter measurement, a diameter of breast height (130 cm height) with a tree growth criterion is a woody plant with Ø > 20 cm. To verify the field identification, vouchers for all trees were collected. Determination of the index of species diversity using the Shannon-Wiener Index with the formula [9]:

$$H = -\Sigma \, (ni/N) \log (ni/N) \tag{1}$$

Where: H = Index of Diversity by Shannon-Wiener
   ni = Important value of species i
   N = Total of important values

The dominance index is useful for determining the type of concentration pattern is calculated by the formula [9]:

$$C = \Sigma \, (ni/N)^2 \tag{2}$$

Where: C = Dominance Index
   ni = Important value of species i
   N = Total of important values

Furthermore, cluster analysis was performed on selected subsets diameter and important value index (IVI) to determine the relationship between species, using MVSP (multivariate statistical package) ver. 3.22 [10]. Cluster analysis is a method of general classification of community sample data [11], expressing species similarities in the sites. The dendrogram representing the diameter and IVI data was drawn by cluster analysis using the unweighted-pair group method with arithmetic mean (UPGMA). Euclidean distance was chosen as the criterion for cluster combination as previously reported [11].

3. Results and Discussions

3.1. Species and diversity composition
The location site contains small areas of mangrove forest, but about 98 % is classified as peat swamp forest. The main tree species found in logged-over peat swamp forest in the study sites were grouped into 3 parts: firstly Dipterocarpaceae family consisting of Meranti flower (*Shorea teysmanniana*) and Meranti stone (*S. uliginosa*), secondly, non Dipterocarpaceae include Balam (*Palaquium hexandrum*), Milas (*Parastemon urophyllus*), Macang (*Mangifera havilandii*), Punak (*Tetramerista glabra*), Jambu (*Eugenia* sp), Banana (*Mezzetia parviflora*), and Arang-arang (*Gynotroches axillaries*), and thirdly particular species of Ramin (*Gonystylus bancanus*) (table 1).

Table 1. Main species detected in three sites

No	NLPSF	3LPSF	4LPSF
1.	*P. hexandrum*	*S. teysmanniana*	*P. hexandrum*
2	*P. urophyllus*	*M. havilandii*	*Eugenia sp*
3	*M. havilandii*	*S. uliginosa*	*S. teysmanniana*
4	*S. uliginosa*	*Eugenia sp*	*M. parviflora*
5	*S. teysmannia*	*G. bancanus*	*G. axillirais*
6.	*T. glabra*	*P. urophyllus*	*T. glabra*

NLPSF = Newly logged-over peat swamp forest, 3LPSF = three years logged-over peat swamp forest and 4LPSF = four years logged-over peat swamp forest

Peat swamp forests are found in oligotrophic waters that allow for peat formation. The patterned peat layer can be intense, reaching 20 m and its diameter can be up to several km. Peat swamp forest is located on the east coast of Sumatra, West Kalimantan and South Kalimantan [3]. The flora is not much different from the lowland Dipterocarpaceae forest and gives similarity to the forest. Common tree species included the genera of *Altentia, Barringtonia, Combretatus, Dactylocladus, Dryobalanops, Ganua, Gonystylus, Shorea, Tetramerista* and *Tristania* also found in peat swamp forest or coastal plant for *Barringtonia* [11]. The peat swamp forest vegetation shows centered zoning. In Kalimantan, peat swamp forests are centered on a sand island, while in Sumatra concentrating on the thickest of peat deposits, increasingly to the margins of reduced peat thickness [1].

A study on three-peat swamp areas in Riau, namely Kiambang Bay, Muara Tolam, and Siak Kecil River shows the composition of species, for example, in Kiambang Bay was dominated by *Durio carinatus, Palaquium burckii, Dyera lowii, Shorea platycarpa, S. uliginosa,* and *S. teysmanniana.* While in the area of Muara Tolam was dominated by *Artocarpus rigidus*, *G. bancanus*, and *P. burckii.* For small Siak River areas, the species are *Strombosia javanica*, *Mezzetia leptopoda*, *P. walsuraefolium*, and *Koompassia malaccensis* [12]. The species distribution areas as mentioned above were almost similar found in this study. This circumstance may occur due to similar edaphic conditions which were glei humus and organosol. Three sites in the Riau region, therefore, have no significantly compositions different species. This study suggested that it is not possible to conclude from the small number of samples of peat swamp forest [13]. Two tree species highly control Topogenous peat swamp forests on the island of Siberut, *Stemonurus secundiflorus* and *Radermachera gigantean* [13].

In general peat swamp forest is dominated by ramin (*G. bancanus*) with several other commercial timber species such as a resin (*Agathis borneensis*) and meranti swamp (*Shorea* spp). The ramin association generally tends to form a typical formation and is thought to be climax vegetation for peat forest [2]. Mirmanto [14] reported vegetation analysis from Sebangun peat swamp forest, Central Kalimantan consisted of the most family of Dipterocarpaceae, Clusiaceae, Myrtaceae and Sapotaceae. Furthermore, *Combretocarpus rotundatus, Palaquium leiocarpum, Stemonurus scorpioides,* and *Tristania whittiana* were the most dominant species found in the site [14].

The present study shows the pattern of classification of species for tree level was more concentrated in the NFLPS (C = 0.12) compared to 3LPSF (0.09) and 4LPSF (0.11) (Table 2). This condition is demonstrated by the significant value of the tree level dominance index in the NFLPS. While the diversity index of species in the tree level is more diverse in the 4LPSF, this circumstance due to the vast diversity of forests of four years logged-over swamp forest (H' = 1.14) and more abundant species composition (21) and a number of families (17) as summarized in table 2.

Table 2. Diversity index and dominance index of the tree in the sites

No	Study site	Diversity index (H')	Dominance index (C)	Number of species	Number of family
1.	NLPSF	0.98	0.12	12	11
2.	3LPSF	1.11	0.09	16	15
3.	4LPSF	1.14	0.11	21	17

NLPSF = Newly logged-over peat swamp forest, 3LPSF = three years logged-over peat swamp forest and 4LPSF = four years logged-over peat swamp forest

3.2. Intergroup cluster analysis

The community may be more uniform or less uniform, and it expresses this similarity in a quantitative and community-based manner [15]. Based on this data we classified tree species in newly, three years, four years logged-over swamp forest (NLPSF, 3LPSF, 4LPSF), respectively, in the form of dendrogram according to UPGMA (unweight pair-group method using arithmetic averages) (figure 2-4).
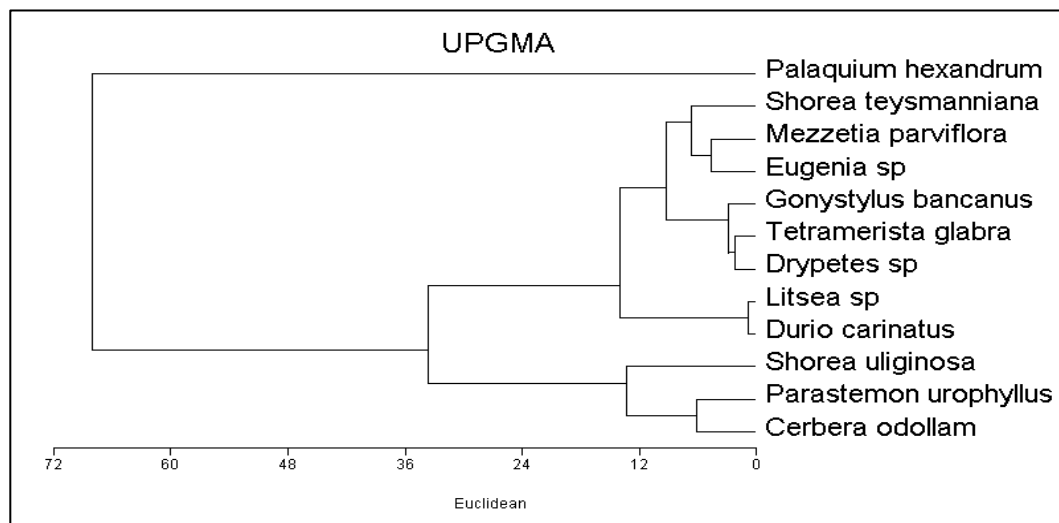
Figure 2. Dendrogram showing species similarity in NLPSF.

Figure 2 shows the relationship between species in NLPSF. The most related types namely *Litsea* sp and *Durio carinatus* converge to form cluster 1 in Euclidean 0.94 inequality distance matrix. The next most closely related types are *Tetramerista glabra* and *Dryptes* sp forming cluster 2 at the distance of Euclidean 2.23 inequality matrix which then unites to form cluster 3 with *G. bancanus* at Euclidean inequality 2.88. The next type is *M. parviflora* and *Eugenia* sp forming cluster 4 on the Euclidean inequality equal to 4.64. Next are *Parastemon urophyllus* and *Cerbera odollam* forming cluster 5 at Euclidean inequality distance of 6.12.and moreover, cluster 4 united to form cluster 6 with *S. teysmanniana* at the distance of Euclidean inequality 6.76, and united with cluster 3 to form cluster 7 at Euclidean different distances 9.23. Cluster 5 united with *S. uliginosa* forms cluster 8 at Euclidean disparities distances 13.29.

Further cluster 1 and cluster 7 join to form group 9 at Euclidean inequality distance 13.96. Between clusters 8 and 9 combines to form cluster 10 at Euclidean inequality distance of 33.59. Finally, bunch ten united with *P. hexandrum* shaped group 11 on Euclidean distance matrices of 68.08. Thus in the NLPSF had 11 clusters.
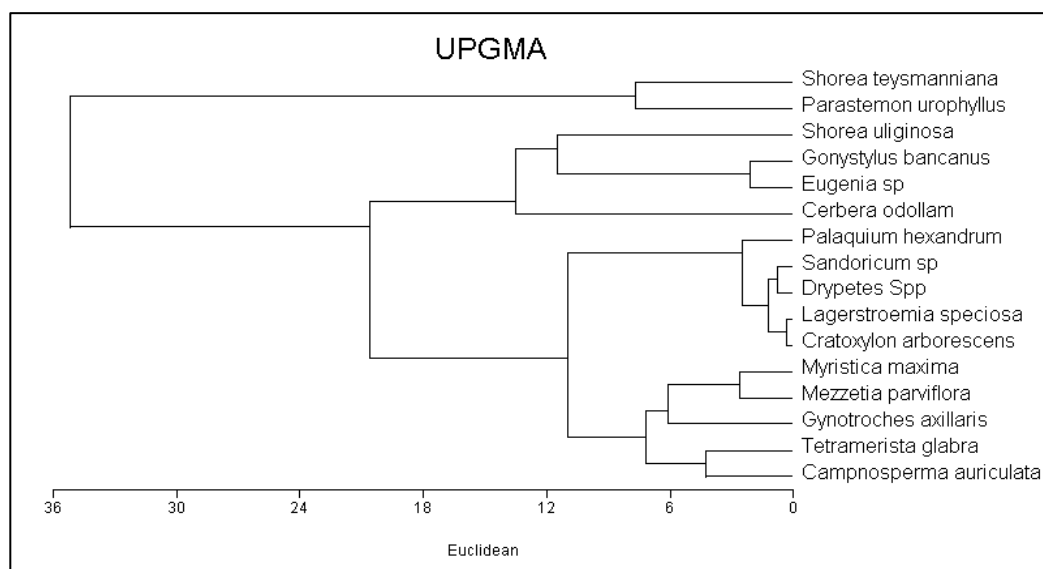

Figure 3. Dendrogram depicting species relationship in 3LPSF

Figure 2 depicts the dendrogram type of tree level in 3LPSF which has 14 clusters. Cluster 1 is a combination of *C. arborescens* and *L. speciosa* species in the Euclidean inequality equation matrix of 0.32. Then cluster 1 united with *Drypetes* spp on the Euclidean inequality equal to 0.81. Finally, cluster 14 is formed on the Euclidean inequality distance matrices of 28.80. Figure 3 displays 20 clusters with Euclidean inequality distance matrices in cluster 20 of 227.91. Cluster 1 is formed between *Litsea* sp and *Myristica maxima* on Euclidean inequality equal to 0.13.
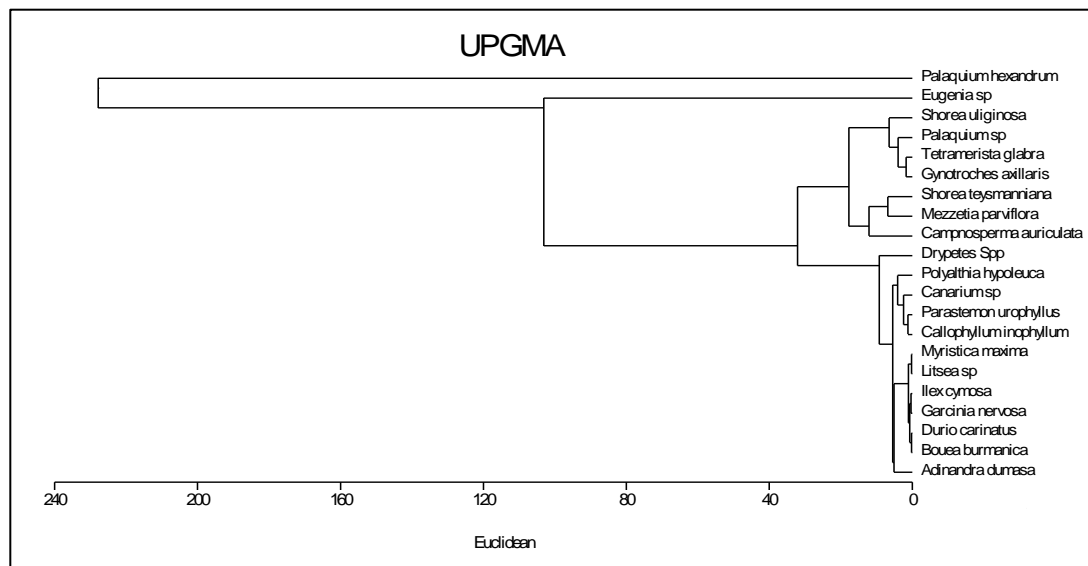

Figure 4. Dendrogram showing species relationship in 4LPSF

The clustering analysis in this study suggested the presence of indicator species [16]. Indicator species are species that are used as an ecological indicator community, habitat type or environmental changes. For example, *P. hexandrum* was distinguishable in the NLPSF and 4LPSF as formed branch alone. However, in the 3LPSF *P. hexandrum* was grouped with other majority species. In this regards, the different sites in this study emerged different indicator species due to a logging operation or other environmental factor [16]. With respect of clustering sites from NLPSF to 4LPSF, it allowed distinguishing among those species that describe individual groups and those explain the similarity between species [5-6]

In Indonesia, this peat swamp forest is based on a field survey distributed in Jambi, Riau, South Kalimantan, Central Kalimantan, South Sumatra, Central Kalimantan, South Kalimantan and West Kalimantan [17]. In peat swamp forest generally found three layers of canopy [17-18]. The top canopy layer is formed by ramin types (*Gonystylus* spp), mentibu (*D. stenostachys*), jelutung (*Dyera lowii*), pisang-pisangan (*M. parviflora*), kalau (*Palaquium* spp), gerunggang (*C. arborescens*) and other species generally less well recognized. The middle canopy layer is usually formed by the types of cashews (*Eugenia* spp), (*Tristania* spp), medang (*Litsea* spp), kandis (*Garcinia* spp), kemuning (*Xantophyllum* sp), pendarahan (*Myristica* spp), kayu malam (*Diospyros* spp). While the bottom canopy layer (ground cover) consists of Annonaceae family, saplings, trees and shrubs of *Crinus* spp, *Pandanus* spp, *Salaca* spp, and other plants, including *Uncaria* sp [17-19].

3.3. The implication to silvicultural practice

Silvicultural practices ensure sustainability when the residual trees left after logging are adequate to regenerate naturally [20]. The species composition of a stand indicates the existence of tree species in forest stands. Information on species composition is used to determine sustainable forest management. Timber harvesting might affect species composition in logged-over forests. With the

application of appropriate silviculture systems and controlled harvesting techniques expected natural regeneration went well, and damage could be suppressed [20]. Concerning the results of this study, silvicultural practice changed the species composition. In the NLPSF, *G. bancanus* was absent and found after three years logged-over. Similarly, Pose et al. [2] described species composition differed before and after logging operation in Sukalnating, West Kalimantan. Prior to harvesting was dominated by *G. bancanus, S. teysmanniana*, however, in the seven years logged-over forest was predominated by *S. pachyphylla* and *Gutta reghas* [2].

4. Conclusions
The species diversity in the study area was varied among sites. Species diversity in tree level is more diverse in 4LPSF compared to other sites. The pattern of a grouping of species for tree level is more concentrated found in the NLPSF.

Acknowledgment

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