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Effect of Drainage Channels on Vegetation Diversity of Tropical Peatswamp Forest of Sebangau National Park, Indonesia

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Fire

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ABSTRACT

Peat swamp forests are playing important role in climate change by carbon storage, biodiversity conservation, and crucial local livelihoods. The construction of drainage channels in Sebangau National Park, Indonesia negatively affects the Peatland ecosystem and degrades the vegetation diversity. This research aims to study the composition and vegetation diversity of secondary peat swamp forests in Sebangau National Park (SNP), especially around large and small drainage channels. For the observation of vegetation composition and diversity, each observation block consisted of 3 transects that were 300 m apart from each other, and perpendicular to the channel. For observations on small drainage channel blocks, transects are made to continue the previous transect at a distance of 500 m from the end of the large drainage channel. On each transect, 5 plots of vegetation were made using the plot line method with a distance of 50 m between each plot. A total of 15 plots of 30mx30m size were prepared for each drainage channel category. Observations were made on the growth rate of seedlings in a 2m x 2m plot, poles in a 5m x 5m plot, saplings in a 10m x 10m plot, and trees in a 20m x 20m plot. The results of the study showed that *Shorea* spp., *Combretocarpus rotundatus*, *Cratoxylum arborencens*, and *Calophyllum* sp. are the dominant plant species of the study area. Overall 92 species were reported from the Large Drainage Channel block and 86 species from the Small Drainage Channel block. Further, the Species Diversity ranged between 1.43 - 1.57 while Species Richness ranged from 16.80 – 23.03, and the

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Evenness Index ranged from 0.83 – 0.92 at all levels of vegetation growth. Results of the study can be concluded that the channel dimensions do not have any effect on species number, diversity index, species richness, and species evenness at all levels of vegetation growth. The Similarity Index of species at seedlings, saplings, and poles is more than 50%, while at the tree level it was reported less than 50%.

1 Introduction

Peatland ecosystems are always associated with water-saturated conditions, high organic matter, and flooded anaerobic conditions. The peatland ecosystem is of global importance because of its high carbon storage, role in global climate change, higher biodiversity, and importance in community livelihoods (Joosten 2015; Wildayana 2017). Parish et al. (2008) suggested that tropical peatland covers one-third of global wetlands, and occupied the area of 440,000 to 600,000 km^2. From the total tropical peatland area, the maximum areas are distributed in Southeast Asia, South America, and Africa's Congo Basin (Page et al. 2011; Gumbricht et al. 2017). Further, it has the most diverse and most threatened peatland environment and is associated with significant carbon emissions by natural decomposition, fires, and biodiversity loss (Page et al. 2006; Yule 2010; Turetsky et al. 2015). In Southeast Asia, particularly in Malaysia, Sumatra, and Kalimantan, peat forest cover has declined from 119,000 km^2 to 46,000 km^2 from 1990 to 2015, while agricultural areas on peatland increased from 17,000 km^2 to 78,000 km^2 during the same study period (Miettinen et al. 2016). Small-scale farmers, industrial oil palm, and expansion of paper pulp are some responsible factors for this agricultural conversion which put this peatland agricultural system is in danger of extinction (Miettinen et al. 2016; Wijedasa et al. 2018; Tan et al. 2021).

Peat swamp forest has very high biodiversity and is a habitat for various flora and fauna including 1,524 plant species, 123 mammals, 268 birds, 75 reptiles, 27 amphibians, and 219 fish species (Page et al. 1997; Yule 2010; Posa et al. 2011; Posa et al. 2011). Along with this, PSF is also an important ecosystem for the primates *Pongo* spp., clouded leopard (*Neofelis diardi*) and cat species, Storm stork (*Ciconia stormi*), white-winged duck (*Asarcornis scutulata*) (Silvius & Verheugt 1986; Morrogh-Bernard et al. 2003; Cheyne et al. 2011; Cheyne et al. 2014).

Thus, national and international efforts have been needed to be enhanced for conserving the remaining peat swamp forest (PSF). Some of the important challenges which affect efforts to restore degraded peatlands are increasing the groundwater level on drained peatlands and the development of economically competitive crop species suitable for paludiculture (Wosten et al. 2008; Wichtmann et al. 2010; Uda et al. 2017; Uda et al. 2017; Evans et al. 2019; Tan et al. 2021). Damage to the peat ecosystem causes disturbance to this diversity (Mishra et al. 2021). Tropical peatland degradation generally begins after converting PSF into a nonforest area for agriculture, smallholder plantations, and industrial forest plantations, which is usually accompanied by drainage channel construction. Changes in land use from PSF to open peat cause serious damage to the ecological function of the peat as a carbon sink and store, in addition to biodiversity. The decrease in forest cover, mainly due to drainage, is also associated with a decrease in the groundwater level, which impact the characteristics of peat soils including the processes of decomposition and compaction that result in an increase in bulk density (Wösten et al. 2006a; Sherwood et al. 2013; Sumargana et al. 2016; Uda et al. 2017; Cooper et al. 2019a; Evans et al. 2019; Sinclair et al. 2020). Bulk density of peat soil is important in regulating the hydrology of peatlands by influencing groundwater storage capacity (Rydin and Jeglum 2015), and reducing the hydraulic conductivity of peat (Päivänen 1973), water retention, and increasing flooding (Hooijer et al. 2012; Könönen et al. 2015; Evers et al. 2017; Evans et al. 2019). The change from PSF to other uses that reduce land cover also changes hydrological functions, especially surface runoff. Anshari et al. (2010) reported that conversion of PSF to open areas by removing vegetation and drainage reduced the C/N ratio, organic acid, and peat soil compaction and increased bulk density and pH of peat soil as a direct result of drainage. Thus, changes in the physical and chemical characteristics of peatlands tend to cause changes in the vegetation structure and composition of peatlands, but empirical studies to investigate the effect of changes in the properties of these peat soils are still limited, especially in tropical peat.

Sebangau forest of Kalimantan, Indonesia, have diverse biodiversity and have more than 215 tree species, 92 non-tree plant species, 73 ant species, 66 butterfly species, 297 spider species, 41 Komodo dragon/damselfly species, 55 fish species, 11 species of amphibians, 46 species of reptiles, 172 species of birds, and 65 species of mammals (Husson et al. 2018). Sebangau National Park (SNP) is one of the Indonesian PSF ecosystems which has relatively good conditions in carbon storage and water regulation as compared to the surrounding area. Therefore, it is necessary to manage it wisely and sustainably because SNP's peat swamps are believed to have high economic and ecological value (Taman Nasional Sebangau, 2011; Khalwani et al. 2017). Resort Mangkok or commonly called SSI (former HPH PT, Sinatra Sebangau Indah), is included in the working area of the National Park

Management Section, Sebangau II, Pulang Pisau Regency. From the 1970s until the mid-1990s, various illegal logging activities were rampantly carried out by people in the Sebangau area. Along with this, the research area was faced forest fires during the long dry season of 1992, 1994, 1997, and 2002. In the early 1970s, the Sebangau River is one of the important transportation routes which mainly used for timber transportation. These activities cause the Sebangau peat-swamp forest area to lose water and damage the hydrological function of the area, causing drought and flammability in the dry season (Taman Nasional Sebangau, 2016).

In general, the PSF ecosystem is easily disturbed, and once it is disturbed it will be difficult to return to its original state. Excessive drainage and fires in the Mangkok Resort area of Sebangau National Park peat swamp ecosystems are likely to cause changes in the structure of the vegetation that grows in these localities. This may also influence the properties of peat soil due to excess drainage which has implications for vegetation growth. Thus, changes in the physical and chemical characteristics of the peatlands will most likely cause changes in the structure and composition of the vegetation of this area. Further, changes in land use from PSF to open peat which is usually associated with drainage seriously damage the various ecological functions including biodiversity (Wösten et al. 2006b; Sumargana et al. 2016; Ida et al. 2017; Cooper et al. 2019b). Furthermore, it has also an impact on the characteristics of peat soil, including the process of decomposition and compaction (Sherwood et al. 2013; Evans et al. 2019; Sinclair et al. 2020).

The expected recovery is a restoration that leads to the original ecosystem, although this is very difficult and takes a very long time, especially with continued disturbances in the ecosystem (Kimmins 1997). The progress of the recovery process can be measured by several factors, one of which is by looking at the composition of the type and structure of the vegetation in the area. This research was conducted to evaluate the effect of large drainage channels and small drainage channels on the plant composition and diversity due to changes in hydrological function in the peat swamp forests.

2 Materials and Methods

The current study was carried out in the area of Mangkok Resort, Sebangau NP, Central Kalimantan, Indonesia (Figure 1). Field observations and data collections were carried out in 2018. Geographically SNP is located at 1°54' – 3°08' South Latitude and 113°20' – 114°03' East Longitude. Further, the study area is located between the 3 regencies/cities namely Palangka Raya City, Katingan Regency, and Pulang Pisau Regency. The topography consists of coastal lowlands with altitudes ranging from 2 to 8 MSL and it is generally a waterlogged wetland area (swamp). The park is covered by deep peat with a thickness of more than 3 m, the study area is also suffered by repeated fire in different areas since 1997, and includes former concession and illegal logging areas with small drainage channels constructed. In the Mangkok Resort research area, water channels were previously used for logging and transporting. This area of about 88 ha and is allocated by SNP for research-based tourism development, including biodiversity research, peatland restoration, and social communities. Various efforts including the construction of 45 canal blocks/dams have been carried out for rehabilitation. The constructed dams have been divided into 3 categories including 10 permanent, 9 semi-permanent, and 26 simple dams (Taman Nasional Sebangau 2016). Hydrological rehabilitation was carried out by constructing large channel blocks in 2006 and small channel block in 2016 (Balai Taman Nasional 2015).

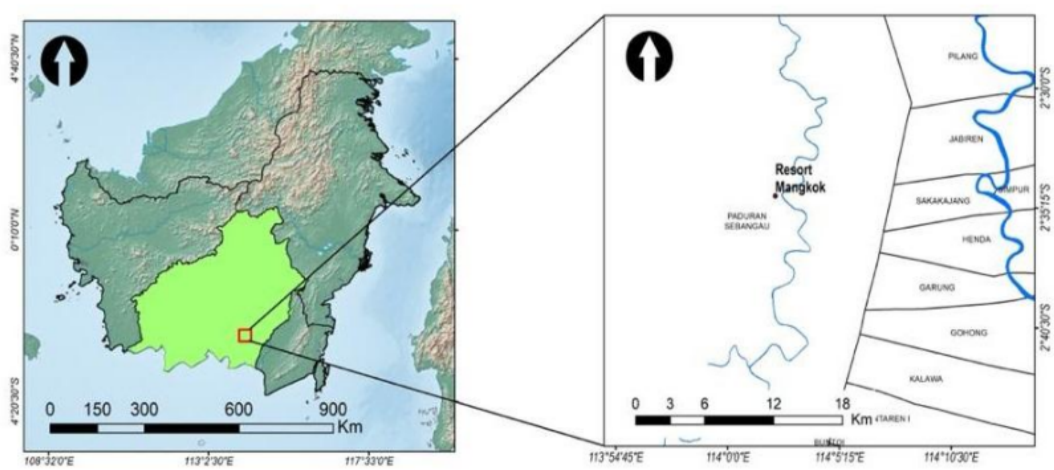


Figure 1 Research location at Sebangau National Park, Central Kalimantan, Indonesia

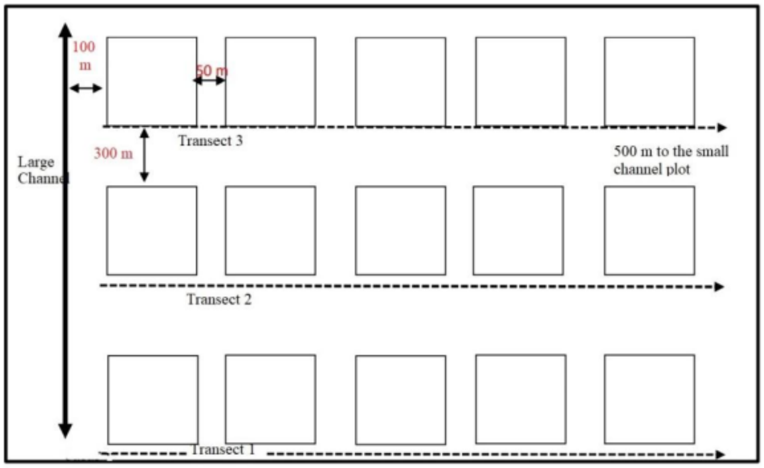


Figure 2 Research Plot Placement Design

⟺ : Channel row; — →: Transect of placement of observation plots; ⟷: Distance between lines and observation plots; 2m x 2m : Plot for seedlings, woody vegetation with height <1.5m; 5m x 5m : Plot for saplings, woody vegetation with height >1.5m and a diameter <10cm; 10m x 10m : Plot for poles level, woody vegetation with diameter 10 cm-<20 cm (all subplots); 20m x 20m : Plot for trees, woody vegetation with diameter >20cm (subplots a, b, d, e)

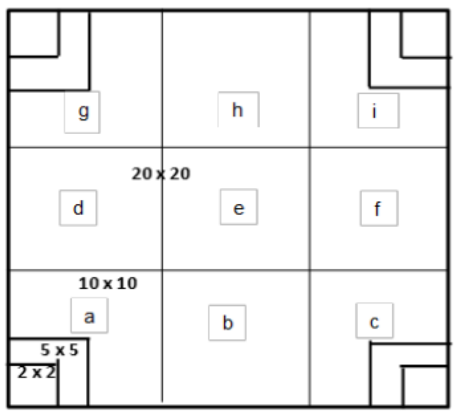


Figure 3 Plot design for Vegetation Measurement

Various observations related to the vegetation diversity including seedlings, saplings, poles, and trees were undertaken from the large and small drainage channels area of Resort Mangkok, National Park of Sebangau. Path design, vegetation category size definitions, and plot placement are shown in Figures 2 and 3.

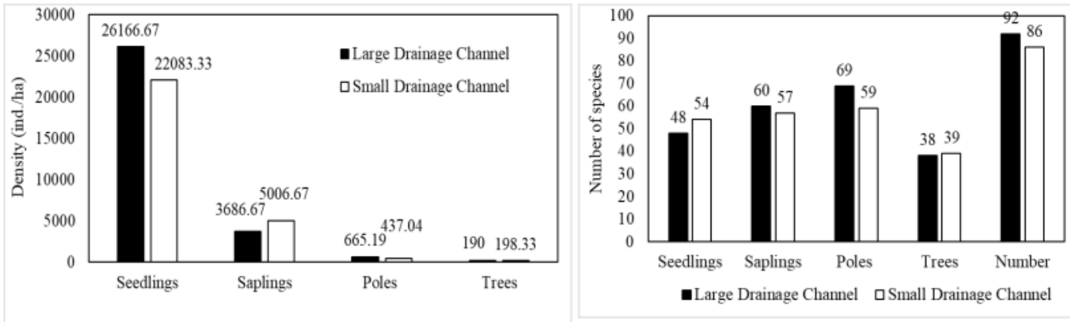
Observation blocks in the study area are located on 2 drainage channels located at Mangkok Resort: the large drainage channel was >10 m wide while the small drainage channel was 2.5 m wide. Vegetation observation blocks were placed systematically near to each channel. Each block was made up of 3 transects separated from each other by 300 m and located at a distance of 50 m from the channel. In each transect, 5 vegetation plots were made using the plot line method (Kusmana 1997). The observation transect on the large channel begins at a distance of 100 meters, perpendicular to the channel. While the small channel transect starts at a distance of about 1000 m from the large channel. Thus, the distance between the end of the large channel observation transect and the beginning of the small channel transect is about 500 meters. The dimensions of the plot was 30 m × 30 m and the total number of plots was 30 (15 for each drainage channel size category). Observations were made on the growth rate of seedlings in a 2m x 2m plot, poles in a 5m x 5m plot, saplings in a 10m x 10m plot, and trees in a 20m x 20m plot Overall, the sample plot area in each research block was 1.35 hectares.

2.1 Data Collection and Analysis

The biodiversity index of species for each plot was calculated using standard parameters including importance value index (IVI), species diversity index, species richness index, species evenness index, and species similarity index (Table 1). Data from vegetation inventory are analyzed to determine the composition and dominance of the species. The dominance of a species will be indicated by the importance value index. Plant density indexed (INP) for pole and tree-level vegetation is the sum of Relative Density (RD), Relative Frequency (RF), and Relative Dominance (RD), while for seedling and sapling level vegetation, the INP value is calculated by the sum of RD + RF (Indriyanto 2006). For the species diversity index, we used the calculation of the Shannon - Wiener Index (Magurran 2004), while for the calculation of the species richness index Margalef Index was used (Margalef 1958). Pielou's evenness index (E_{Pielou}) (Magurran 2004) was used for species evenness index, while for the species similarity index Kent's (2011) method was used.

Table 1 Equations for calculating index diversity of species

Index	Equation	Description	References
Important value index	Relative Density + Relative Frequency + Relative dominance		Indriyanto 2006
Relative Density	$\frac{\text{The density of a species}}{\text{Total Density of all species}} x\,100$		
Species Density	$\frac{\text{Number of a species}}{\text{Total Area Sampled}}$		
Relative Frequency	$\frac{\text{Area of plot in which species occur}}{\text{Total Area Sampled}}$		
Frequency of Species	$\frac{\text{Area of plot in which species occur}}{\text{Total Area Sampled}}$		
Relative Dominance	$\frac{\text{Dominance of a species}}{\text{Total Dominance of all species}} x\,100$		
Dominance of species	$\frac{\text{Total basal area of a species}}{\text{Total Area Sampled.}}$		
Index of Species Diversity (H')	$H' = -\sum_{i=1}^{s}\left(\frac{ni}{N}\right)\ln\left(\frac{ni}{N}\right)$ H' = Shannon - Wiener Index ni = Number of individuals species N = Total number of individuals	The magnitude of the Shannon-Wiener species diversity index is as follows: a. H' > 3, species diversity is abundant with a high number of individual wealth. b. H' 1 ≤ H' ≤ 3, species diversity is moderate. c. H' < 1 indicates that the diversity of species is low or low	Magurran 2004
Index of Species Richness (R)	$Dmg = \frac{S-1}{\ln N}$ Dmg = Margalef's Index S = Number of species observed N = Total number of individuals of all species in the sample Ln = Natural logarithm	Margalef's index (R) criteria are: a. R<3.5; low density b. 3.5<R<5.0; medium density c. R>5.0; high density	Margalef 1958
Index of Species Evenness (E)	$E = \frac{H'}{\ln S}$ E = Index of Species Evenness (0-1) H'= Shannon_Wiener Index S = Number of Species	The evenness index ranges between 0 and 1; 0 indicates that the evenness level is very uneven; whereas if the value is close to 1, almost all species that exist, have the same abundance (Magurran, 2004)	Magurran 2004
Similarity Index (SI)	$SI = \frac{2C}{(A+B)}$ SI= Sorenson Similarity Index A= Number of species from sample A B= Number of species from sample B C= Number of similar species in both samples A and B	SI>50 means the area has the same species in the community; SI<50%, then there are differences in the types of community constituents in the area or do not even have the same types.	Kent, 2011



(a) (b)

Figure 4 (a) Density and (b) Number of Species at all Growth Level

3 Results and Discussion

3.1 Species Composition and Dominance

Total 112 tree species have been reported from the vegetation analysis near the large and small channel blocks observation of Sebangau. The number of species reported from the large drainage channel blocks was not different from the reported from the small drainage channel (Figure 4). Around the large channel block, there were a total of 92 species, consisting of 48 seedlings, 60 saplings, 69 poles, and 38 adult tree species (Annexure 1). Meanwhile, around the small drainage block, there were a total of 86 species, consisting of 54 seedlings, 57 saplings, 59 poles, and 39 adult tree species. The conditions in these 2 blocks with a decrease in vegetation density with a pattern like a letter "J" upside down (Figure 4a), indicated that the stand structure was still normal and the regeneration process was running well. Based on the density values of the 2 studied blocks the pattern is as seedlings > saplings > poles > trees. These results are in line with several previous researchers Indriyanto (2006), Sidiyasa (2009), and Hidayat (2014) who reported similar regeneration processes. Competition for space utilization, soil nutrients, and sunlight causes the normal pattern of the regeneration process. In addition to the influence of environmental factors, it turns out that changes in vegetation density are influenced by growth and deaths (Indriyanto 2006), which leads to a reduction in the number of surviving individuals at each growth stage (Kusmana and Susanti 2015). One of the indicators of forest restoration is the creation of natural regeneration, which is marked by the growth of natural regeneration and the resilience of species diversity. However, not every species can regenerate because it is possible to change the dominant species at each growth stage.

In the case of types of species, a wide variation was reported between the studied drainage channel blocks, and the species found in large drainage channel block are not reported from the small drainage channel block. The major species reported from the large drainage channel block are *Aglaia* sp. (Bangkuang Napu), *Alstonia spatulata* (Pulai), and *Anisoptera* sp. (Katimpun), while *Ardisia* sp. (Kayu Bulu), *Artabotrys suaveolens, Blumeodendron kurzii* (kenari) are the major species which found in small drainage channel blocks. Furthermore, tree species that are always reported from the large channel are *Calophyllum inophyllum* (Kapur naga), *Calophyllum nodusum* (Kakal), *Calophyllum soullatri* (Takal), *Calophyllum* sp. (Panaga jangkar).

In general, the species composition obtained from this study was not so much different than the other studies in different locations of SNP. Similarly, the number of species reported from the PSF block ranged from 100 to 113 species (Page et al. 1999; Mirmanto 2010; Nugroho 2011; Siahaan et al. 2014). Furthermore, Nugroho (2011) suggested that among the studied species the dominant species was *Palaquium leiocarpum* Boerl.v. The findings of Kalima and Denny (2019) and Qirom et al. (2019) are slightly different from the present study and they reported fewer species ranging from 47 – 96 species from the different locations of SNP. Furthermore, the composition and types of species outside SNP are also very diverse; Astiani (2016) stated that the results of research on degraded PSF in Riam Berasap, West Kalimantan and found 108 species from the three types of land cover namely > 10 years after logging (low), 5-10 years after felling (medium), and degraded forest (open area or former fire). This variation in the number of species shows that PSF species composition is very dynamic, and these species variations are related to the location and time of observations. Similar types of diversity in species compositions were reported by Page et al. (1999), Mirmanto (2010), and Mofu (2011). Page et al. (1999) found that in PSF habitat sub-types peat depth increases towards the center of the Sebangau peat dome.

The absence of a significant difference in the number of species between the Large Channel Block and the Small Channel Block indicates that the channel size does not affect the number and types of the vegetation. So far there has been no publication that directly relates the dimensions of the canal to the groundwater level on peatlands, but the water level in the canal and the distance from the

Table 2 Dominant Species along with the Large and Small Drainage Channels

Observation Block	Growth Level	Local Name	Latin Name	IVI (%)
Large Drainage Channel	Seedlings	Tatumbu	*Syzygium havilandii*	17.74
		Gerunggang	*Cratoxylum arborescens*	16.86
		Tatkal	*Callophyllum soullatri*	13.45
	Saplings	Kemuning	*Xanthophyll eurhynchum*	15.09
		Malam-Malam	*Dyospyros bantamensis*	13.68
		Gentalang	*Palaquium sp.*	11.85
	Poles	Gerunggang	*Cratoxylum arborescens*	44.17
		Belangeran	*Shorea balangeran*	14.81
		Trending	*Campnosperma coriaceum*	13.21
	Trees	Belangeran	*Shorea balangeran*	33.25
		Rahanjang	*Xylopia fusca*	24.47
		Gerunggang	*Cratoxylum arborescens*	18.66
Small Drainage Channel	Seedlings	Kemuning	*Xanthophyll eurhynchum*	26.72
		Jambu Hutan	*Syzygium sp.*	23.98
		Jambu-Jambu	*Syzygium incarnatum*	15.37
	Saplings	Kemuning	*Xanthophyll eurhynchum*	22.53
		Jambu Hutan	*Syzygium sp.*	20.38
		Belangeran	*Shorea balangeran*	10.16
	Poles	Belangeran	*Shorea balangeran*	29.88
		Malam-Malam	*Dyospyros bantamensis*	18.31
		Manggis Hutan	*Garcinia banana*	18.22
	Trees	Malam-Malam	*Dyospyros bantamensis*	28.57
		Belangeran	*Shorea balangeran*	28.30
		Tumih	*Combretocarpus rotundatus*	25.55

canal significantly change the characteristics of peat, especially bulk density (Astiani et al. 2017; Sinclair et al. 2020). The results of the study showed that drainage ditches in peatland landscapes lowered the water level more than 3 times, and it reached from 11.7 cm to 37.3 cm. The impact of this drainage channel on the water level is worse in dry months (July-August). The lowering of the peat water level makes changes the microclimate of the soil, especially the temperature and water content of the peat. Astiani et al. (2017) also reported that changes in land use on peat along with drainage development also affected the peat water level.

As shown in Table 2 dominance of the species is described by the IVI value of standing vegetation. The upright vegetation in the study area was dominated by *Shorea balangeran* (Balangeran) which were present at almost all growth levels of both studied blocks. Further, *S. balangeran* is a commercial species that is almost extinct in its natural habitats (Wardani and Susilo 2016) and can be categorized as a species that is resistant to growth and regeneration in burned forests (Atmoko 2011). In addition, this tree species cannot tolerate shaded conditions and it required light for its normal growth and that's why it is well acceptable under the studied environmental conditions (Wibisono et al. 2005). Species dominance also came from pioneer species, such as *Combretocarpus rotundatus*, *Cratoxylum arborescence*, and *Calophyllum* sp. and this indicates that this location is highly disturbed by drainage, fire, or waterlogging. In peatlands affected by fires, species from the genus Calophyllum are generally found, and the species such as *C. rotundatus*, *Palaquium sp*., and *C. arborencens* were reported from the studied areas also (Astiani 2016; Simbolon 2004; Yulianti et al. 2009). The channel of the study area causes excessive drainage, which results in repeated droughts and fires in the Mangkok Resort area. The results of the current study suggest that repeated fires made changes in vegetation composition and disrupt natural regeneration processes.

The findings of Hoscilo et al. (2011) also suggested that repeated fires causes land cover changes and mostly it is dominated by non-timber vegetation such as ferns or tree mosaics.

3.2 Species Diversity Index (H')

The species diversity index is a parameter that can describe the state of succession or community stability (Goodman 1975; Subiandono and Heriyanto 2016; Pamoengkas et al. 2019). Further, a community can keep itself stable, despite disturbances to its components. Kalima and Denny (2019) stated that forest communities consist of various types of plants, the older the forest stand, the species diversity becomes higher. The diversity index values for each growth stage at the large drainage channel block and small drainage channel block are presented in Figure 5. All values of the species diversity index (H') at various growth stages fall between 1.43 and 1.57, which means the species are abundant and well distributed. The results of the calculation of the diversity index also show that the size of the drainage channel does not affect the value of the species diversity index, although the highest H' value was observed for the large drainage channel block (1.46-1.57) but it was lower than the peat swamp forest area of Sumatra, which ranges from 2.89-2.96 (Istomo and Aziz 2021).

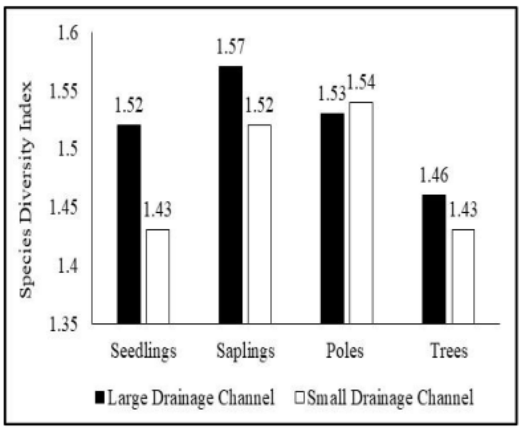


Figure 5 Index of Species Diversity at all Growth Level for both types of channel

3.3 Species Richness Index (R)

Ismaini et al. (2015) stated that species richness is the number of species in a community, where a larger number of species found have the highest species richness index. The Margalef richness index divides the number of species by natural functions, showing that an increase in the number of species is inversely proportional to an increase in the number of individuals. According to Magurran (2004), an R-value <3.5 indicates low species richness, while a value of 3.5 to 5 indicates moderate species richness, and an R-value > 5 indicates high species richness. The species richness index in the large drainage channel block is in the range of 16.80 – 23.03 while it was reported 18.31- 20.93 for the small drainage channel (Figure 6). The highest species richness value 23.03 was at the poles growth stage of the large drainage channel. The species richness index of the Sebangau research area is higher than other research sites of the peat swamp forest area of Sumatra where it was reported between 5.18-6.51 (Istomo and Aziz 2021).

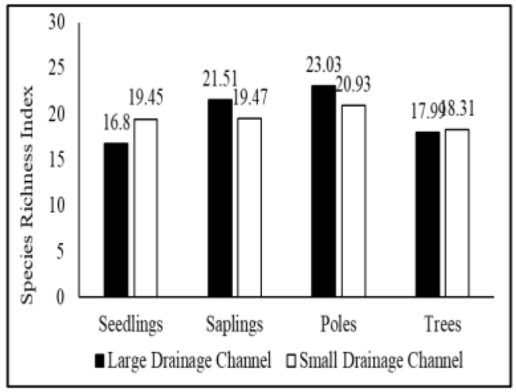


Figure 6 Index of Species Richness at all Growth Level

3.4 Species Evenness Index (E)

The evenness index value is used to measure the degree of evenness of the abundance of individual species in the community. It describes the balance between one community to another. It is stated that if the value of E is close to 1, the evenness is high (Soegianto 1994; Sidauruk 2016). According to Kusnadi (2015), the highest evenness index is directly proportional to the species diversity index. According to Magurran (2004), if an evenness value is close to 1 indicates that a community is more evenly distributed, whereas it is increasingly unevenly distributed if the value is close to zero. The evenness index value is strongly influenced by the diversity index and the number of species. The evenness index is directly proportional to the species diversity

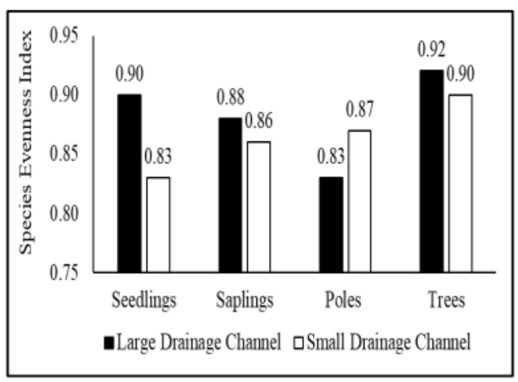


Figure 7 Index of Species Evenness at all Growth Level

index, the higher diversity index values also have the higher evenness index values (Odum 1993). Further, if the species diversity index is low and the number of species is also low the evenness index value will be also small.

As shown in Figure 7, the Evenness Index (E) of the two studied blocks is high with a value range of 0.83 – 0.92 at various growths stages; and this was slightly higher compared to Gunawan et al. (2012), where the E value was reported between 0.77 and 0.84. The highest values were found for adult trees near both large and small drainage channel which suggest that these are the species with a relatively equal and even number of individuals. Further, the species evenness index for both the studied block was very high which suggested that species are evenly distributed in both the studied blocks. This is also suggested that the channel size has no significant effect on the resulting evenness index value.

3.5 Species Similarity Index (SI)

Results related to the similarity values for all growth levels have been given in Table 3, which suggests that the similarity values between large and small channel blocks are in the range of 46.75 - 73.44%. The similarity of species was shown at the various growth stages of seedlings, saplings, and poles with SI values > 50%, while in the case of adult trees SI value was reported 46.75% which showed higher dissimilarity. Djufri (2003) suggests that if the SI value is greate0072 than 75% the similarity criterion is very high, while when it is in the range of 50 - 75%, 25 – 50%, and < 25% it comes under the categories of high similarity, low similarity, and very low similarity respectively. Many tree species are that are present in the large channel are not found in the small channel and vice versa. This phenomenon occurs because the forest conditions are relatively nonhomogeneous. Barbour et al. (1987) suggested that individuals of the same type will occupy relatively homogeneous microsite conditions because these species naturally have developed adaptation and tolerance mechanisms to their habitat. Loveless (1983) also suggested that physical and chemical factors along with animals and humans' activities also determined the types of plant or plant community.

According to the Taman Nasional Sebangau (2016) reports, the forest fire is more common around the large channel and this might be responsible for the smaller value of the similarity index. Further, variations in environmental, physical, and chemical conditions and the interactions between the study area species also affect the similarity index, and as a result study area also had low category vegetation similarity (Loveless 1983). Barbour et al. (1987) suggested that individuals of the same type occupy relatively homogeneous microsite conditions and this helps species to naturally developed adaptation and tolerance mechanisms for their habitat.

Conclusion

The channels were constructed as part of a previous logging concession in the PSF area of Mangkok Resort, SNP. Results of the study suggested that although the construction of channels resulted in the over-drainage which developed the dry conditions and increased the chances of forest fires but after this also vegetation composition did not show any significant changes in the study area. Further, in terms of variations in distance from the river and peat depth, the number of species recorded in this study is higher than the previous studies in the same location, but it is not so much different from the studies conducted in other locations of SNP. Study area vegetation is dominated by *Shorea spp, C. rotundatus, C. arborencens,* and *Calophyllum* sp. Results of the study also suggested that the dimensions of the drainage channel seem did not affect the number of species, species diversity index, species richness index, and evenness index. Further to better establish the influence of the existence of channels on the composition and diversity of vegetation types in SNP and other degraded PSF areas the consistency can be tested by making observation blocks on the channel that have been recently rehabilitated.

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Table 3 Species Similarity Index (SI %) at Observation Block

Growth stage	Number of Species		Number of Species found in both blocks	SI (%)
	Large Drainage Channel	Small Drainage Channel		
Seedlings	48	54	31	60.78
Saplings	60	57	41	70.09
Poles	69	59	47	73.44
Trees	38	39	18	46.75

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Annexure 1 List of Species Found at the Research Site

Species	Family	Large Channel	Small Channel
Acronychia pedunculata	Pteridaceae	√	√
Adinandra sp.	Pentaphylacaceae	√	√
Aglaia rubiginosa	Meliaceae	√	√
Aglaia sp.	Meliaceae	√	X
Alseodaphne coriacea	Lauraceae	X	√
Alstonia spatulata	Apocynaceae	√	X
Anispotera sp.	Dipterocarpaceae	√	X
Antidesma coriaceum	Phyllanthaceae	√	√
Antidesma diandrum	Phyllanthaceae	√	√
Archidendron borneense	Fabaceae	√	X
Ardisia sp.	Primulaceae	X	√
Artabotrys suaveolens	Annonaceae	X	√
Artocarpus sp.	Moraceae	√	X
Baccaurea bracteata	Phyllanthaceae	√	√
Barringtonia longicephala	Meliaceae	√	√
Beilschmiedia glabra	Lauraceae	√	√
Blumeodendron kurzii	Euphorbiaceae	X	√
Calophyllum inophyllum	Calophyllaceae	√	√

Species	Family	Large Channel	Small Channel
Calophyllum nodusum	Calophyllaceae	√	√
Calophyllum soullatri	Calophyllaceae	√	√
Calophyllum sp. 2	Calophyllaceae	√	√
Calophyllum sp. 3	Calophyllaceae	√	√
Calophyllum sp. 4	Calophyllaceae	√	√
Calophyllum venulosum	Calophyllaceae	√	√
Campnosperma coriaceum	Anacardiaceae	√	√
Carallia brachiata	Rhizophoraceae	√	X
Castanopsis tungurrut	Fagaceae	X	√
Combretocarpus rotundatus	Anisophylleaceae	√	√
Cratoxylum arborescens	Hypericaceae	√	X
Crudia tenuipes	Fabaceae	√	X
Cryptocarya crassinervia	Lauraceae	√	√
Dacrydium pectinatum	Podocarpaceae	√	X
Dactylocladus stenostachys	Crypteroniaceae	X	√
Dialium sp.	Fabaceae	√	√
Diospyros bantamensis	Ebenaceae	√	√
Diospyros perfida	Ebenaceae	√	X
Diospyros pseudomalabarica	Ebenaceae	√	√
Diospyros siamang	Ebenaceae	X	√
Diospyros sp. 2	Ebenaceae	X	√
Dipterocarpus borneensis	Dipterocarpaceae	√	X
Dryobalanops beccarii	Dipterocarpaceae	√	X
Dyera lowii	Apocynaceae	√	√
Elaeocarpus glaber	Elaeocarpaceae	√	√
Elaeocarpus mastersii	Elaeocarpaceae	√	√
Elaeocarpus palembanicus	Elaeocarpaceae	X	√
Elaeocarpus parvifolius	Elaeocarpaceae	√	√
Eugenia elmerii	Myrtaceae	√	√
Evodia speciosa	Rutaceae	√	X
Fagraea racemosa	Gentianaceae	√	√
Ficus sp. 1	Moraceae	√	√
Ficus sumatrana	Moraceae	√	X
Garcinia bancana	Guttiferae	√	√
Gardenia tubifera	Guttiferae	√	√
Gluta sp.	Anacardiaceae	√	X
Gnetum cuspidatum	Gnetaceae	√	X
Gonystylus bancanus	Thymelaeaceae	√	√
Gymnacranthera farquhariana	Myristicaceae	X	√
Horsfieldia sp.	Myristicaceae	√	√

Species	Family	Large Channel	Small Channel
Ilex cymosa	Aquifoliaceae	√	√
Ilex hypoglauca	Aquifoliaceae	√	X
Koompassia malaccensis	Fabaceae	√	√
Lithocarpus conocarpus	Fagaceae	√	√
Lithocarpus sp.	Fagaceae	√	X
Litsea lanceolata	Lauraceae	X	√
Litsea noronhae	Lauraceae	√	√
Litsea sp.	Lauraceae	X	√
Litsea sp. 1	Lauraceae	√	√
Lophopetalum javanicum	Celastraceae	√	X
Madhuca motleyana	Sapotaceae	√	√
Mallotus sp.	Euphorbiaceae	√	√
Mezzettia sp.	Annonaceae	√	√
Microcos sp. 3	Malvaceae	√	√
Myristica maxima	Myristicaceae	X	√
Myristica sp.	Myristicaceae	X	√
Neoscortechinia kingii	Euphorbiaceae	√	√
Nephelium maingayi	Sapindaceae	√	√
Palaquium ridleyi	Sapotaceae	√	√
Palaquium sp. 1	Sapotaceae	√	√
Palaquium sp. 2	Sapotaceae	√	√
Parartocarpus venenosa	Moraceae	√	√
Platea sp.	Icacinaceae	X	√
Pouteria malaccensis	Sapotaceae	√	√
Pternandra coerulescens	Melastomataceae	X	√
Sandoricum beccarianum	Meliaceae	√	√
Santiria apiculata	Burseraceae	√	√
Shorea balangeran	Dipterocarpaceae	√	√
Shorea sp. 2	Dipterocarpaceae	√	√
Shorea sp. 3	Dipterocarpaceae	√	X
Shorea teysmaniana	Dipterocarpaceae	X	√
Shorea uliginosa	Dipterocarpaceae	√	√
Stemonurus secundiflorus	Stemonuraceae	X	√
Sterculia sp.	Malvaceae	√	√
Syzigium lineatum	Myrtaceae	√	√
Syzigium sp. 1	Myrtaceae	X	√
Syzigium sp. 3	Myrtaceae	√	√
Syzygium chloranthum	Myrtaceae	√	√
Syzygium havilandii	Myrtaceae	√	√

Species	Family	Large Channel	Small Channel
Syzygium incarnatum	Myrtaceae	X	√
Syzygium zeylanicum	Myrtaceae	√	X
Tarenna fragrans	Rubiaceae	√	X
Tetractomia tetrandra	Rutaceae	√	√
Tetramerista glabra	Tetrameristicaceae	√	√
Tristaniopsis merquensis	Myrtaceae	√	√
Tristaniopsis sp. 2	Myrtaceae	√	X
Urophyllum sp.	Rubiaceae	√	X
Vatica sp.	Dipterocarpaceae	√	√
Xanthophyllum eurhynchum	Polygalaceae	√	√
Xanthophyllum stipitatum	Polygalaceae	√	X
Xerospermum sp.	Sapindaceae	√	√
Xylopia fusca	Annonaceae	√	√

Note: √ = Available; X = Not available

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