INTERNATIONAL JOURNAL
OF
CONSERVATION SCIENCE

ISSN: 2067-533X   Volume 16, Issue 2, 2025: 1051-1064   www. ijcs. ro

DOI: 10. 36868/IJCS.2025.02.19

DISTRIBUTION OF TREE VEGETATION TYPES AS BIOINDICATORS FOR LAND CONSERVATION IN SULTAN SYARIF HASYIM FOREST PARK, RIAU

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Abstract

This study examines TPH levels in soil and flora diversity in Sultan Syarif Hasyim Grand Forest Park (Tahura SSH). Flora surveys were conducted at seven TTM locations using purposive sampling with 20x20m transect plots. Data were analyzed for species richness, density, diversity, evenness, and their correlation with vegetation using regression analysis and PCA in PAST 4.05. TPH levels decrease with soil depth, mostly concentrated at 0-50 cm. Land typology varies, with TH4, TH5, and TH7 as secondary forests, while TH6 is swamp-dominated. Biological indicators show no significant differences between TTM and non-TTM areas but vary with land typology. The highest species diversity occurs at TH2 (TTM) and TH7 (non-TTM), with H' values of 4.16 and 4.19. Secondary forest cover positively correlates with species richness (R^2 = 67%), density (61%), diversity (90%), and evenness (58%). PCA analysis links biological indicators positively with Alseodaphne peduncularis and Shorea acuminata but negatively with Acacia mangium (an invasive species) and Vitex pinnata (a swamp indicator).

***Keywords**: Flora; Biological Indicators; Grand Forest Parks; Oil Contaminated Soil; Forest Typology; Total Petroleum Hydrocarbons*

Introduction

Flora, or vegetation in forests, has a very important role in regulating environmental climate and also as a provider of environmental services [1]. Plants can reduce carbon dioxide (CO_2) levels in the air through the process of photosynthesis, in which some of the carbon that is broken down will be stored as carbon stock in the plant body [2]. High CO_2 levels in the atmosphere contribute to global warming, which will also have an impact on other disasters such as weather anomalies, pollution, floods and other disasters that have a negative impact on the environment [3] so that flora diversity becomes very important [4]. One effort to maintain flora diversity is by conserving flora through conservation forests such as national parks and grand forest parks [5]. In Vietnam, global conventions related to biodiversity have had a positive impact on nature conservation efforts [6]. Riau Province has one of the grand forest parks, which is a conservation area for various types of flora, such as the Sultan Syarif Hasyim Grand Forest Park (Tahura SSH). Sultan Syarif Hasyim Grand Forest Park (from now on

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abbreviated as Tahura SSH) is one of the conservation forest areas in Riau Province, which was established based on the Decree of the Minister of Forestry and Plantation No. 348/Kpts-II/1999 dated 26 May 1999 and the Decree of the Minister of Forestry Number: SK.336/Menhut-II/2011 dated 24 June 2011. The Tahura SSH area has an area of 6,172ha, of which 3,041.81ha is in the Regency area Kampar, 2,323.33ha in the Siak Regency area and 806.86ha in the Pekanbaru City area [7, 8]. Several human activities, such as inappropriate land conversion and construction, have an impact on land patterns and quality, such as changes in vegetation cover [9]. Several oil companies in Riau have oil mining operations around the Tahura SSH area. Oil spills were found in parts of the Tahura SSH area, which were thought to be oil spills from past oil mining industry activities. Oil spills cause a decrease in soil quality or productivity [10], which will also have a negative impact on the flora that grows on the land [11]. There are six locations in Tahura SSH located around two rivers whose soil is contaminated with petroleum. Mitigation efforts have been carried out to reduce the spread/expansion of petroleum-contaminated land (TTM) in the Tahura SSH area.

Crude oil spills in an ecosystem are very difficult to recover from naturally [12]. Crude oil spills have a significant negative impact on the environment for a very long time if remediation efforts are not carried out [13, 14]. Recovery efforts at TTM must be carried out immediately so that the quality of the soil becomes productive again and the flora that grows on it can develop well [15]. However, efforts to restore environmental functions in SSH Taura also have the potential to have an impact on the SSH Taura flora due to the implementation of TTM excavations. Therefore, before restoration of environmental functions is carried out, initial baseline information is needed regarding the depth of the TTM and the diversity of the SSH taura flora in the locations in question. Apart from looking at the existing conditions of the Tahura SSH location, which was affected by crude oil spills, this research provides information on the diversity of flora in the Tahura as a reference in preparing an ecosystem restoration plan at Tahura SSH.

Material and Methods

Place and Time

This research was conducted from August 2022 to February 2023 and was carried out in the Sultan Syarif Hasyim (Tahura SSH) Minas Grand Forest Park area, Riau Province (Fig. 1).

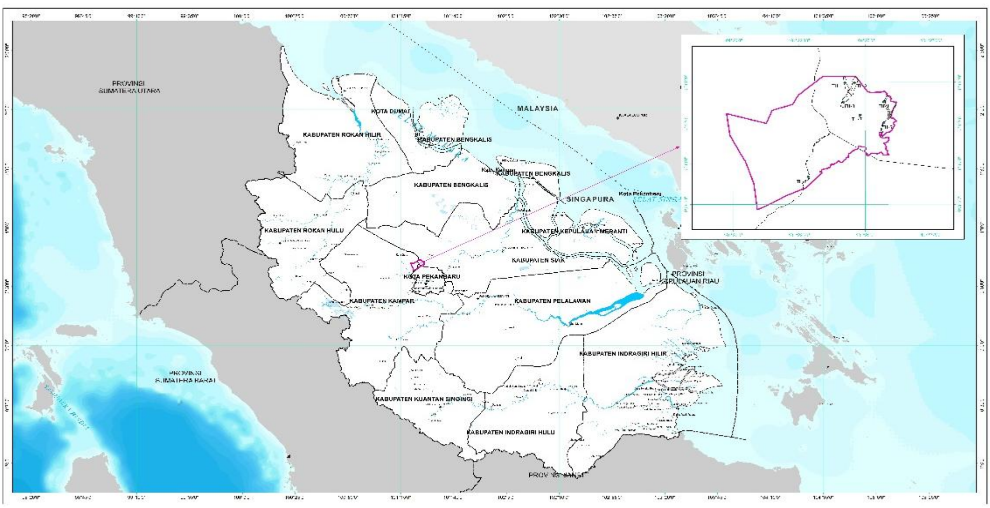

Fig. 1. Research sites. TH1= Minas 7B-89B, TH2= Minas 8B-48 PLG, TH3= Minas 8B-48 JP, TH4= Minas 8C-83, TH5= Minas 8C-96, TH6= Estuary, TH7= Surrounding Natural Forest (HAS)

Study Area

Flora inventory surveys were carried out at six TTM locations, including Minas 7B-89B, Minas 8B-48 PLG, Minas 8B-48 Pesantbridge, Minas Tahura 8C-83, Minas 8C-96 and Muara Estuary. Each location is divided into grids measuring 100×100m, each of which is also further divided into plots measuring 20×20m. The number of plots that were observed purposively in all locations where TTM was located refers to data provided by companies that have work areas around Taura. As a comparison, observations were made outside the six areas mentioned above. In this survey, these additional locations are called "Surrounding Natural Forests," or HAS for short. This additional location is known to not have a TTM.

Procedures

Based on the TTM location data provided by the oil company, which has a working area near the Taura area, transects and observation plots measuring 20×20m were made (Fig. 2).

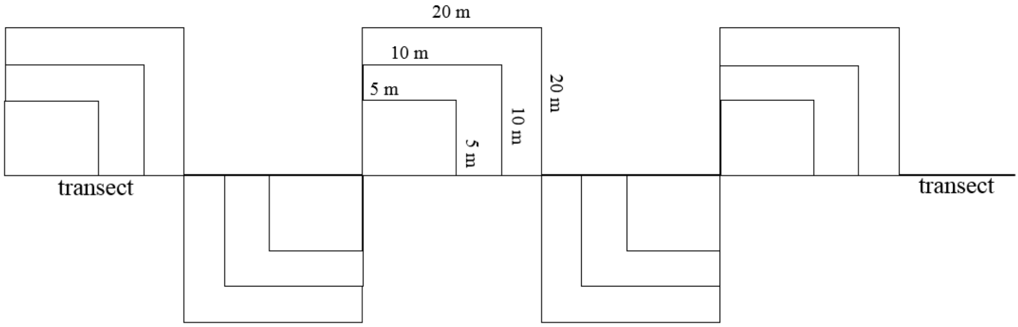

Fig. 2. Research Sampling Plot Design

However, the number of plots and the total area of observation fields or the length of transects in this research are adjusted to the area of each location containing TTM spots. Virtually an Avenza map has also been prepared for surveys at each location to facilitate navigation in the field to plots that have been designated as observation plots. Each type of tree is identified and adjusted to the name listed in World Flora Online (WFO) or Plant of The World Online. Each tree's trunk diameter at breast height (dbh) was calculated using a measuring tool.

Data Analysis

Some biotic indices were analyzed by determining relative density, relative frequency, importance value index, Shannon-Wiener species diversity index, species richness, evenness and rate of endemism using the following formula [16-18]:

1.Density = number of individual species/area of the plot.

2.Relative Density (RD) = (density of a species/density of all species) x 100%.

3.Frequency = number of plot occupied by a species/total number of plots.

4.Relative Frequency (RF) = (frequency of a species/frequency of all species) x 100%.

5.Important Value Index (IVI) = RD + RF

6.Shannon-Wiener species diversity index (H') = $H' = -\sum P_i \times \ln P_i$, $P_i = n_i/N$

H'= Species diversity index

ni = Important value index of a species

N = Total number of important value Index

ln = Natural log

7.Eveness index (E) = $E = H'/\ln(s)$

E = Eveness index

H' = Species diversity index

ln = Natural log

S = Number of species.

Species richness was recorded by counting the number of species found. Plant species were grouped into local or endemic species and exotic or introduced species based on the natural distribution of the Malesiana phytoregion. The degree of endemism was determined by the equation: (density of local or endemic species/total species density) x 100% [19]. The diversity index between two sites was compared by the diversity t-test. The data will also be analyzed by regression to see interactions or correlations between parameters and then the data will be analyzed by PCA (Principal Component Analysis) using PAST 4.05 software.

Results and discussion

Levels of Oil-Contaminated Soil in Tahura

The dominant soil types in the Tahura SSH area are tropodults (red-yellow podzolic) and tropaquepts (alluvial). Tropodults are scattered on hillsides and mountains. Tropaquepts soil is spread on the banks of the river. The soil texture of the AI horizon is sandy loam and clayey loam; the deeper you go, the higher the clay content. The soil structure is crumbly to angular lumps for horizon A and angular lumps to compressed for horizon B. Soil conditions like this generally have low permeability. The results of TPH analysis on TTM in Tahura show variations in TPH levels at each soil depth in Tahura (Table 1).

At the TTM location, a very significant difference was found between the TPH content at a depth of 0-50cm and the TPH content at a depth of 50-200cm, where the greater the depth, the lower the TPH content. At non-TTM locations, TPH was also found, although in very small amounts. The TPH content in the soil at several TTM locations in Tahura is 0-50cm deep with a range of 37,200-88,500mg/kg (3.72-8.85%) and an average of 73,333mg/kg (7.33%).

Tabel 1. Soil TPH levels in Tahura

Origin	Dept (Cm)	Number of Sample	TPH Value	
			Range (mg/Kg)	Average (mg/Kg)
	0 – 50	6	37.200 – 88.500	73.333
TTM	51 - 100	6	40 – 3.110	895
	101 - 150	6	41 - 498	137
	151 – 200	6	40 - 342	97
	0 – 50	6	45- 145	79
Non TTM	51 - 100	6	-	<40
	101 - 150	6	-	<40
	151 – 200	6	-	<40

Information: TTM = Oil Contaminated Soil

This data shows that the soil TPH content at the TTM location can be found from a depth of 0-200 cm, but very high content is only found at a depth of 0-50cm. The value exceeds the pollution threshold (1% or 10,000ppm) according to Minister of Environment Decree No. 128 of 2003. TPH values at deeper depths (50-200m) are much lower (<40-3,110mg/kg) and below the TPH threshold set by the Indonesian Ministry of Environment.

Several previous studies have shown that the TPH content in various TTM samples in Riau varies. The TPH concentration in TTM in oil mining wells in Siak is around 2.4% [21]. The TPH value in TTM samples from Minas is around 1.17% and the TPH content in TTM samples in the Rokan Block operating area is around 1.81 to 3.68% [22]. The TPH content in TTM in other regions also shows values above the threshold. As a comparison, the TPH content in TTM from oil well locations in Kawengan District, Bojonegoro Regency, East Java, reached 5.84% [23]. The TPH concentration in TTM in Veneto, Italy, is lower, namely around 2,029-2,313mg/kg [24]. TPH concentrations at 6 Canadian locations showed lower TPH values, namely around 150-3,590mg/L [25]. Several factors cause differences in TPH concentrations in various locations contaminated with crude oil, for example, differences in exploitation history.

Differences in management and the number of oil wells influence the amount of TPH that is wasted into the ground [23].

The TPH content of soil samples near the soil surface at the TTM location is higher compared to soil samples at depths above 50cm, which are very low or even undetectable. This is in accordance with findings in various oil-polluted land locations, which also show variations in TPH content. TPH concentrations in surface soil samples from mangrove forests in Maharashtra, India, ranged from 0.5 to 20,800mg/kg with an average value of 2,031.1mg/kg. In comparison, TPH concentrations in deeper soil samples ranged from 0.5 to 17,040mg/kg. With an average value of 1,964.4mg/kg. Some locations show higher TPH concentrations at the surface, but in other locations, TPH concentrations are higher in deeper soil samples [26].

Flora at TAHURA SSH

Sultan Syarif Hasyim Grand Forest Park has various typologies (Table 2). This variety of typologies also causes variations in species and flora community structure at each observation location. Based on Table 2, it can be seen that only locations TH4, TH5 and TH7 are all classified as secondary forests. Secondary forests are classified as forests that have varied constituent vegetation and have ecosystem services that are important enough to be preserved [27]. Other locations have variations in typology, such as plantations, open land, horticulture and swamps. The TH6 location is dominated by swamp typologies such as swamp forest and swamp thicket. Swamp ecosystems have high soil carbon reserves [28], high humidity and high organic matter content, but phosphorus levels and pH values tend to be low [29]. Peat swamp forests have different canopy structure metrics; peat swamp forests have a lower and simpler canopy profile compared to other forest typologies [30]. At the TH1 location, the proportion of secondary forests and plantations is almost the same, thus influencing the presence of constituent vegetation in that location. The issue of converting primary and secondary forest land into plantations has resulted in a decrease in the diversity of existing vegetation. Excessive expansion of plantations and monoculture farming in Mount Halimun Salak National Park is reported to have an impact on land use and disrupt conservation objectives, causing a decline in the diversity of existing vegetation [31]. In general, the plantation typology in the Tahura area is oil palm plantations, so this has a direct impact on the variation in vegetation species that make up Tahura. The increase in plantation area for the PO (Palm Oil) industry is based on the high economic value of oil palm plantations, so many cases of oil palm plantations encroach on forest areas [31].

Table 2. Land typology from each location

Typology	Typological Extent (%)						
	TH1	TH2	TH3	TH4	TH5	TH6	TH7
Secondary Forest	55,34	84,2	88,91	100	100	20,34	100
Plantation	44,66	0,02	0	0	0	5,93	0
Open field	0	12,7	0	0	0	0	0
Horticulture	0	3,08	0	0	0	0	0
Swamp	0	0	11,09	0	0	73,73	0

Information: TH1= 7B-89B, TH2= 8B-48PLG, TH3= 8B-48 Broken Bridge, TH4= 8C-83, TH5= 8C-96, TH6= Estuary, TH7= Surrounding Natural Forest

Some of the flora found in Taura are species that are difficult to find in other forests. Species from the Dipterocarpaceae family known as the family of meranti species Merantian are species that are currently quite rarely found in forests, especially in the Sumatran area, because the economic value of wood from species in this family, such as the meranti species (*Shorea sp.*), has a very high economic value [32, 33]. This causes several species in Tahura SSH to be very important to maintain. Based on observations made, 51 families were found consisting of 191 species. The total species from each location can be seen in figure 3.

Figure 3 explains that the TH2 location has more varied flora species compared to other locations. Species variation on land depends on many environmental factors, such as land typology [34]. This is because the TH2 location is dominated by secondary dry land forest, so this causes the vegetation at that location to be more varied. Dryland forests have quite a high vegetation cover [35]. The secondary dryland forest type has various functions as ecosystem services whose sustainability needs to be maintained [36]. The location of the estuary is the location with the fewest flora species compared to other locations. Swamps dominate the location of the estuary, so the land typology is very open and the variety of tree species in that location is very minimal compared to other locations. Swamp forests are reported to have simpler vegetation formation compared to other forest types [37]. Not many plants are able to live in wet areas, causing the variation in upper vegetation to be lower compared to dry forests [38].

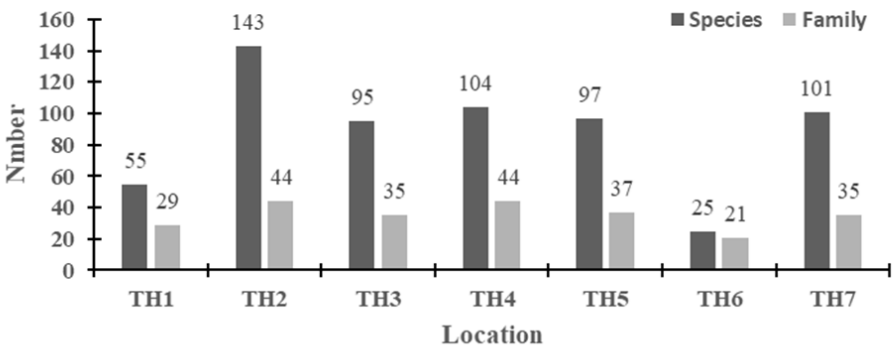

Fig. 3. Floral species and families for each location. Information: TH1 = 7B-89B, TH2 = 8B-48PLG, TH3 = 8B-48 Broken Bridge, TH4 = 8C-83, TH5 = 8C-96, TH6 = Estuary, TH7 = Surrounding Natural Forest

Meanwhile, for natural forest locations around the flora species, there is less variation due to several factors such as density (Fig. 4) and land typology. Variation of species in forests is influenced by vegetation density and forest typology. Density, or density of vegetation, influences competitive interactions between vegetation species [39] so that competition causes vegetation selection to occur [40] and influences biological indices such as species richness [41].

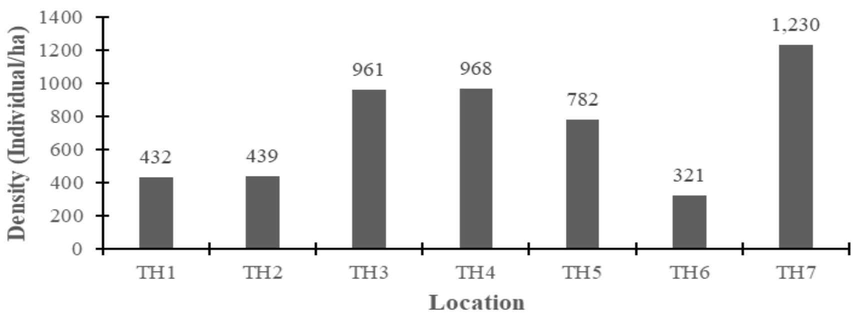

Fig. 4. Tree density at each location. Information: TH1 = 7B-89B, TH2 = 8B-48PLG, TH3 = 8B-48 Broken Bridge, TH4 = 8C-83, TH5 = 8C-96, TH6 = Estuary, TH7 = Surrounding Natural Forest

Density is one of the causes of species variation in land due to competition between species. As vegetation becomes denser, it will also influence other environmental factors, such as light intensity and soil nutrients [42]. Land with primary forest typology in watershed areas is reported to have lower density values but has higher species variation compared to other forest typologies [43]. TH7 is the location with the highest tree density compared to different locations, with a density of 1,230trees/ha. This is because the surrounding natural forest location is dominated by secondary forest, so the density is relatively higher compared to other locations. The TH6 location is the location with the lowest density because there is very little vegetation found at that location, the open land typology also causes the estuary location to have the least variety of species. With the high density and variety of flora species on land, the diversity of existing species, both forest flora and fauna, will increase, especially soil fauna [44].

Diversity and Evenness of species

Species diversity can be the basis of various policies for sustainable management of land. High or low diversity and evenness of species depend on various things such as species variation, species density, land typology and human mobility. The research locations in the Tahura SSH area also have variations in species diversity and evenness (Fig. 5).

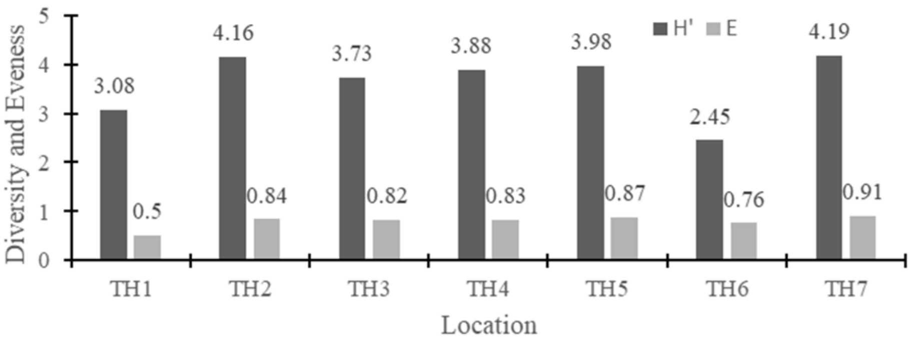

Fig. 5. Diversity and evenness of species in each location. Information: H = Diversity, E = Evenness, TH1 = 7B-89B, TH2 = 8B-48PLG, TH3 = 8B-48 Broken Bridge, TH4 = 8C-83, TH5 = 8C-96, TH6 = Estuary, TH7 = Surrounding Natural Forest

Locations TH2 and TH7 are locations with very high diversity, as well as very high evenness of species. In general, there are no striking differences in species diversity and evenness between locations included in TTM and non-TTM areas. The TH7 location is a non-TTM location, meaning that at this location, there were no oil spills that disturbed the flora. However, other locations, such as TH2, which is included in the TTM area, have relatively the same diversity as TH7. This difference in diversity is more likely to occur due to differences in land typology. TH7 is more dominated by secondary forest land typology compared to TH1 and TH6 locations, which are dominated by open and swamp typologies. The high species richness, or variety of species, in an ecosystem will cause the diversity in that ecosystem to also be higher [45]. Species diversity will be proportional to species richness and species evenness [46]. The condition of absence of TTM spills at the TH7 location further supports the flora that lives at this location to develop well compared to other locations, but the typology factor is dominant. Soil contaminated with petroleum affects the development, growth and productivity of organisms such as plants [47]. Physiologically, the hydrocarbon content in TTM is reported to cause a decrease in total leaf chlorophyll by 21% [48, 49]. This factor causes several locations with a dominant typology to be open, resulting in lower species diversity in those locations. Location TH6 is the location with the lowest diversity compared to other locations and is classified as medium, but the evenness of species is quite high. TH6 is a location with an open typology and is one of the locations where TTM was found. Of all the locations, the evenness at the TH1 location is the location with the lowest evenness, with evenness classified as medium.

There is a correlation between the land typology of each location and biological indicators such as the diversity index and other biological indicators (Fig. 7).

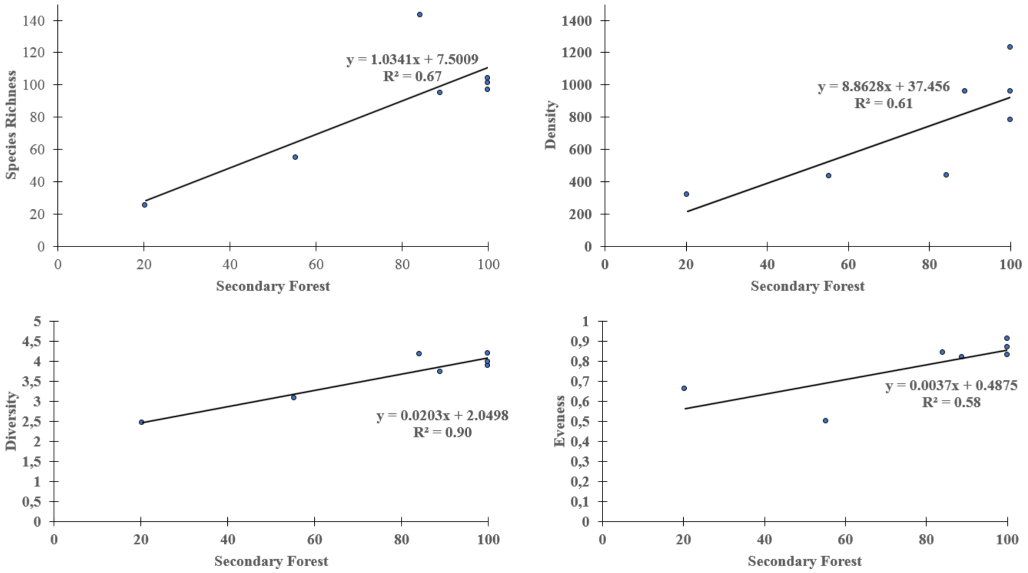

Fig. 6. Correlation between secondary forest typology and biological indicators in Tahura SSH.
Note: *= significant <0.05

Each constituent variable in an ecosystem has its interaction or correlation, both negative and positive. There is a positive interaction between the typology that makes up the location, namely secondary forest and biological indicators such as species richness, density, diversity and evenness of flora. Secondary forests are considered to have less diverse vegetation than primary forests. However, secondary forests have a more diverse variety of vegetation species and have better canopy cover than other types of forests besides primary forests [50-52]. Secondary forests have a more complex composition than agricultural forests and swamp forests, so the contribution of secondary forest ecosystem services both ecologically, socially and economically is very important to maintain [53, 54]. Secondary forest typology in Tahura SSH has a significant positive interaction with species richness, vegetation density, diversity index and evenness index with coefficient of determination (R2) values of 67%, 61%, 90% and 58%, respectively. The greater the relative area of secondary forest typology in an area, the higher the four biological indicators will be.

Species Distribution

Seeing the correlation and distribution of species and biological indicators is very important in further policy making. By looking at this distribution, you can understand the characteristics of each observation location. Several flora species dominate each observation location in Tahura SSH, as well as biological indicators such as species diversity, species evenness, total species and total families (Fig. 7).

Based on Figure 7, it can be seen that TH7 has similar flora characteristics and biological indicators with other locations, such as TH2, TH4 and TH5, but is very different from locations TH3, TH1 and TH6. Location TH7 is characterized by high vegetation density, species evenness, species diversity, total spxecies, total families and a high abundance of *Alseodaphne peduncularis* and *Shorea acuminata* species. However, location TH7 is also characterized by low levels of *Vitex pinnata* species and low levels of *Acacia mangium* species. The species *Alseodaphne peduncularis*, or its local name, medang, is often found in tropical rainforest areas. Some parts of the plant, such as the leaves, which show strong cytotoxic activity against cancer cells, have been developed into a potential ingredient for anti-cancer treatment and the plant can also be used as an essential oil [55, 56]. Shorea acuminata, better known by its local name, meranti, is a type of flora with hardwood characteristics, extensive canopy cover and quite a large stem biomass, so this type has high economic value [57]. Based on the economic value of the Shorea acuminata species, currently, this species is quite difficult to find in other forest areas [33].

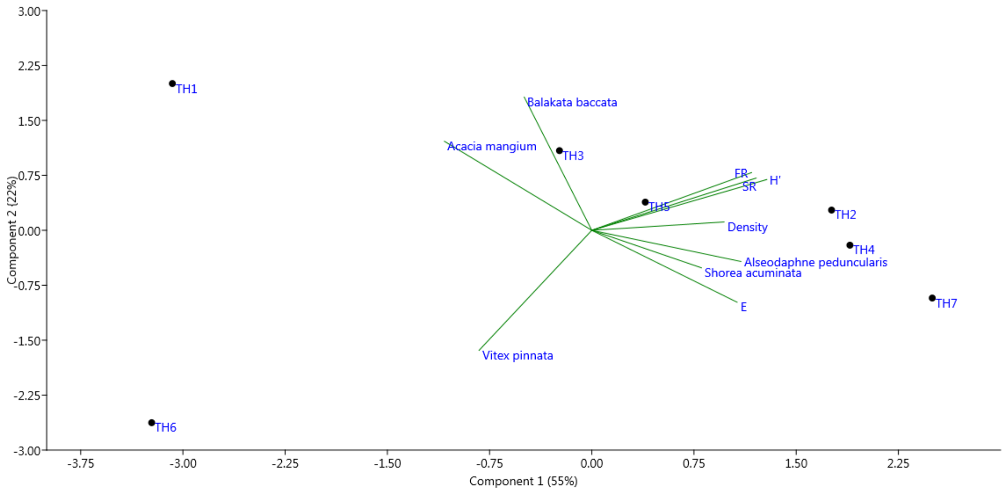

Figure 7. Distribution of several species and biological indicators at various observation locations in Tahura SSH. Information: H= Diversity, SR= Species Richness, FR= Familly Richness, E= Evenness, TH1= 7B-89B, TH2= 8B-48PLG, TH3= 8B-48 Broken Bridge, TH4= 8C-83, TH5= 8C-96, TH6= Estuary, TH7= Surrounding Natural Forest

Location TH6 is characterized by a high abundance of *Vitex pinnata* species but is also characterized by very low levels of biological indicators and several other species, as is location TH1. The Vitex pinnata species, or its local name known as laban, is generally found in swamp and peat areas but is also reported to be found in secondary dry forests [58]. *Vitex pinnata* is known as a species that is resistant to fire, so that when a forest fire occurs the plant does not die because it is burned and can then regenerate [59]. So, this species has become one of the important species in the swamp ecosystem [60], especially in the peat swamp ecosystem, which is very flammable during the dry season. Peat swamp lands often experience fires, where from 2001 to 2020, more than 33% of peatlands in Riau experienced repeated fires [61]. *Vitex pinnata* lives in relatively wetlands and receives high light intensity, such as in riverside areas and swamps [62]. This explains that this species can be used as a bioindicator for wetland typology and high light intensity.

The high presence of *Acacia mangium* species at the TH1 location indicates that the location has experienced enough damage so that the TH1 location has low biological indicators compared to other locations. Based on the results of the PCA analysis, a negative correlation can be seen between the presence of *Acacia mangium* and high levels of biological indicators such as species richness, density, diversity and evenness of species. This analysis proves that this species is a bioindicator of land degradation, predominantly open land or land that has been damaged. *Acacia mangium*, or acacia, is a type of fast-growing flora that is classified as an alien and invasive species [63]. So, the presence of this species endangers the survival of other flora species. The dominant presence of the *Acacia mangium* species in a land or forest indicates that quite severe damage has occurred in that forest [64].

Conclusions

There are variations in Total Petroleum Hydrocarbon (TPH) levels at soil depth; the greater the soil depth, the lower the TPH level and vice versa. The highest soil TPH levels are in soil with a depth of 0-50cm. Observation locations also have variations in the typology of their constituents, causing differences in the diversity of flora within them. However, in general, there is no difference between TTM and non-TTM locations, where the highest diversity is at locations TH7 (non-TTM) and TH2 (TTM) with the H' value amounting to 4.19 and 4.16 and is classified as high, while the lowest is at the TH6 location with an H' value of 2.45 and is classified as medium. The highest density was at the TH7 location with a value of 1230 individuals/ha, while the lowest density was at the TH6 location with a value of 321 individuals/ha. There is a positive correlation between land typology in the form of the relative area in the form of secondary forest and biological indicators in the form of species richness, density, species diversity and evenness of species with a coefficient of determination (R2) value of 67%, 61%, 90% and 58%, respectively. Based on the PCA analysis, it can be seen that high levels of biological indicators have a positive correlation with the presence of the flora species *Alseodaphne peduncularis* and *Shorea acuminata* but have a negative correlation with the presence of the flora species *Acacia mangium* and *Vitex pinnata*, where *Acacia mangium* is a species that is classified as an invasive alien. This also explains that the *Acacia mangium* species is a bioindicator tree species for degraded or damaged land. In contrast, the *Vitex pinnata* species is a bioindicator tree species for wetland typologies such as swamps and riverside areas in the Sultan Syarif Hasyim Forest Park.

Acknowledgments

The author would like to thank the management of the Sultan Syarif Hasyim Forest Park for assisting with this research. The authors also thank colleagues from the Ecological Research Institute (ERI), Pekanbaru, Indonesia, who have assisted in collecting field data. The author also thanks the anonymous reviewers who were willing to review this journal publication.

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Received: July 30, 2024
Accepted: April 08, 2025