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Analysis of NDVI and Plant Vegetation Diversity in the Traditional Zone, Mount Halimun Salak National Park, Bogor

Salma Khairunnisa, Prijanto Pamoengkas, Adisti Permatasari Putri Hartoyo

Department of Silviculture, Faculty of Forestry and Environment, IPB University, IPB Darmaga Campus, Bogor, 16680, Indonesia

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ABSTRACT

Mount Halimun Salak National Park's (MHSNP) traditional zone is a zone that is highly utilized by the local community to fulfill their daily needs by utilizing non-timber forest resources and implementing an agroforestry system with the main commodities being *poh-pohan* (*Pilea melastomoides*) and *Pinus merkusii*. Forest monitoring in the MHSNP traditional zone is very important as part of sustainable forest management. This study aimed to assess the vegetation density based on NDVI values, evaluate the extent of diversity among plant species, stand structure in the traditional zone of MHSNP, and the correlation between NDVI values and the total species and tree density. Furthermore, the data collection of plant species diversity in the area was based on the NDVI value of vegetation density. The NDVI values were obtained for three classes with different land conditions. The class 1 value range of 0.147 to 0.273 indicates a low vegetation density. Class 2, ranging from 0.273 to 0.319, had a medium vegetation density. Meanwhile, class 3 had a high vegetation concentration, with a value ranging from 0.319 to 0.433. The diversity of plant species included 60 different species from three classes. The density of seedlings is lower than that of saplings, and at the poles, trees are decreasing, indicating a balanced stand structure. The NDVI values showed a positive correlation with total species and tree density. The NDVI values from remote sensing can describe the total species and tree density in the traditional zone of the MHSNP.

Introduction

Forest is a natural resource that can be renewed and has a very important role in which its existence needs to be maintained and managed wisely so that its functions can be optimally and sustainably utilized for the welfare of the community [1]. Sustainable forest management has become an important issue in forest development, as it has been realized the exploitation of natural resources can lead to environmental degradation. If forests are not managed properly, deforestation can occur, which is a change in the cover of an area that previously had canopy cover from forest (tree vegetation with a certain density) to non-forest (no tree vegetation or even no vegetation) [2].

MHSNP is a conservation area which was initially divided into several forest functions that were protected, permanent production, and limited production forest under the management of *Perum Perhutani* which was later changed after the enactment of Minister of Forestry Decree No. 175/Kpts-II/2003 became a unified conservation area for MHSNP with the status of a protected forest area [3]. The MHSNP currently has a conservation function that aims to reduce deforestation and degradation rates, with a total area of ± 87,699 ha [4]. In addition, the forest in MHSNP is a tropical forest ecosystem in West Java that needs to be maintained because it is related to its ecological function in maintaining the balance of the surrounding environment [5].

MHSNP's management is divided into several zones that are the cultural zone, core zone, special zone, utilization zone, rehabilitation zone, jungle zone and traditional zone. The MHSNP traditional zone is highly

Corresponding Author: Salma Khairunnisa ppam@apps.ipb.ac.id Department of Silviculture, Faculty of Forestry and Environment, IPB University, IPB Darmaga Campus, Bogor, Indonesia.

utilized by the local community to fulfill their daily needs by utilizing non-timber forest resources. It is managed by the community through the execution of a specific agroforestry framework. An agroforestry system constitutes a combination of at least one type of woody plant and agricultural, livestock, and/or fishery crops on the same land [6]. Local people maintain agroforestry exist within the conventional region of MHSNP, with the main commodity being *poh-pohan* (*Pilea melastomoides*), which is used as a dish for raw vegetables, and *Pinus merkusii* as a woody plant.

Forest monitoring in the MHSNP traditional zone is very important to do as part of sustainable forest management. As traditional zone management is very similar to local communities, forest monitoring is needed, especially to monitor forest degradation through changes in vegetation density. Remote sensing is an alternative method of forest management. Remote sensing technology, which is currently being developed, can be used for forest monitoring and is far superior in terms of cost, wide area coverage, lower costs, and can be used continuously when compared to field surveys [7]. One frequently employed remote sensing technique involves the utilization of the Normalized Difference Vegetation Index (NDVI). NDVI is an index describing the greenness of a plant, and is calculated based on the pixels of the normalization discrepancy in the image between the near-infrared and red bands [8]. NDVI can be used to estimate and analyze things related to vegetation cover [7]. Research on the diversity of vegetation types, especially in the MHSNP traditional zone, using the NDVI approach, has never been conducted. Hence, it is crucial to undertake investigations pertaining to the variety of vegetation types in the MHSNP traditional zone as an effort to monitor forests and strengthen the database on the diversity of plant species found in the MHSNP traditional zone. This study aimed to analyze the density of vegetation based on NDVI values, examine the degree of diversity among plant species, stand structure in the traditional zone of MHSNP, and the correlation between NDVI values and the total species and tree density.

Method

Study Area

The research is conducted within the traditional zone of Mount Halimun Salak National Park (MHSNP) in Tamansari Village, Tamansari District, Bogor Regency (Figure 1). Administratively, the area of MHSNP is situated across three districts: Bogor, Sukabumi, and Lebak. Tamansari Village in the Tamansari Subdistrict is one of the villages, part of which is either within or directly adjacent to the MHSNP's region. According to the Regional Regulation of Bogor District Number 3 Year 2021 concerning Amendments to Regional Regulation Number 4 Year 2019 Regarding the Medium-Term Regional Development Plan of Bogor District for the Year 2018-2023, the types of soil in Tamansari Subdistrict are dominated by volcanic materials, including latosol.

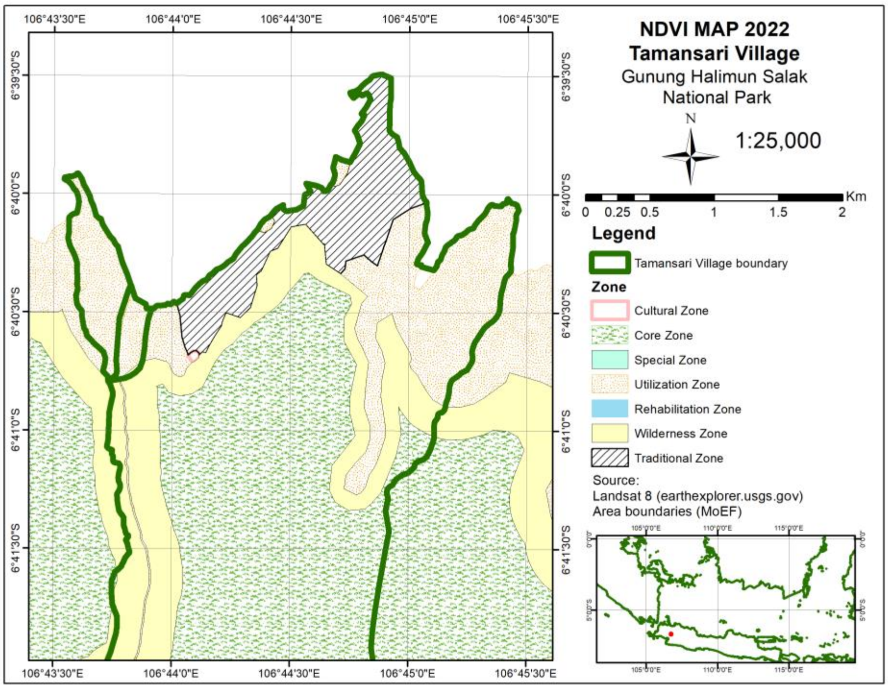

Figure 1. The research area in the MHSNP traditional zone.

Method of Collecting Data

Data collection was conducted by first creating a density map which began with downloading Landsat 8 imagery data from *www.earthexplorer.usgs.gov* with UTM 48S, path/row 122/065, imagery date on March 27, 2022, and downloading MHSNP boundary data from the Ministry of Environment and Forestry and MHSNP zoning boundaries from MHSNP. The data that had been obtained were then processed with the ArcMap 10.8 application by using a vegetation index, the NDVI in the Tamansari Village area in MHSNP, and then a reclass was conducted. The results obtained were three classes of vegetation density based on canopy cover: areas with low vegetation density (class 1), medium vegetation density (class 2), and high vegetation density (class 3) that naturally break from the ArcMap 10.8 application.

Based on the vegetation density which had been created in the MHSNP traditional zone, five sample research plots were constructed in each density class with a size of 50 × 50 m^2 each. In each of these plots, subplots measuring 2 × 2 m^2 were constructed for seedlings and understoreys, 5 × 5 m^2 for saplings, 10 × 10 m^2 for poles, and 50 × 50 m^2 for trees. Moreover, the fundamental data collected were species names, count of individuals, and diameter measurements to analyze the level of plant species diversity and stand structure.

Data Analysis

NDVI (Normalized Difference Vegetation Index)

In the process of crafting a vegetation density map in ArcMap 10.8, the calculation of NDVI was imperative. The NDVI values were determined using a dedicated formula that considers the normalized difference between near-infrared and visible light. This method facilitated the creation of a comprehensive vegetation density map within the ArcMap 10.8 platform. NDVI was determined through the utilization of the formula provided below [9]:

$$\text{NDVI} = \frac{(\text{NIR - Red})}{(\text{NIR + Red})} \quad (1)$$

Composition and Species Diversity

Deriving species composition involved identifying species, quantifying individuals, and considering basal area in the calculation process to yield the Important Value Index (IVI). This calculation method entails assessing the significance of each species based on the amalgamation of these parameters. The IVI computation, delineated subsequently, provides a comprehensive measure of the relative importance of individual species within the ecological framework. The calculated IVI serves as a valuable metric for understanding the ecological relevance of each species in the examined context. The IVI calculation is as follows [10]:

$$\text{Density (K)} = \frac{\text{Number of individuals of each species(N)}}{\text{Sample plot area (ha)}} \quad (2)$$

$$\text{Relative Density (KR)} = \frac{\text{Density of a species (N/ha)}}{\text{Density of all species (N/ha)}} \times 100\% \quad (3)$$

$$\text{Frequency (F)} = \frac{\text{Number of plots found species}}{\text{Number of all plots}} \quad (4)$$

$$\text{Relative Frequency (FR)} = \frac{\text{Frequency of a species}}{\text{Frequency of all of species}} \times 100\% \quad (5)$$

$$\text{Dominance (D)} = \frac{\text{The total of the based areas of a species } (\text{m}^2)}{\text{Sample plot area (ha)}} \times 100\% \quad (6)$$

$$\text{Relative Dominance (DR)} = \frac{\text{Dominance of a species } (\text{m}^2/\text{ha})}{\text{Dominance of all of species } (\text{m}^2/\text{ha})} \times 100\% \quad (7)$$

$$\text{IVI (\%) poles and trees} = \text{KR + FR + DR} \quad (8)$$

$$\text{IVI (\%) seedling and sapling} = \text{KR + FR} \quad (9)$$

The level of species diversity in an area can be determined by measuring several diversity indices. The Shannon-Weiner diversity index was used to determine the level of species diversity in the forest stand [11]. the Margalef Index for species richness serves as an indicator for the augmentation of species. The evenness index is used to show whether the distribution pattern of a species is even [11]. The species dominance index was utilized to ascertain the prevalence of a species within the community [12]. The several diversity indeces were calculated using the following formula [13].

Shannon-Weiner diversity index (H’):

$$H' = \sum_{i=1}^{s} \left(p_i \ln p_i\right) = \sum_{i=1}^{s} \left[\left(\frac{n_i}{N}\right) \ln \left(\frac{n_i}{N}\right)\right] \quad (10)$$

Note:

H' = Shannon-Wiener diversity index

ni = Number of individuals of each species

N = Number of individuals of all species

pi = Abundance of each species

Margalef Species Richness Index (R):

$$R = \frac{(S-1)}{\ln N} \quad (11)$$

Note:

D = Margalef species richness index

S = The count of species within the habitat

N = The sum of individuals across all species in the habitat type evenness index (E)

Species Evenness Index (E)

$$E = \frac{H'}{Ln\ S} \quad (12)$$

Note:

E = Species evenness index (E)

H' = Shannon-Weiner diversity index

S = Simpson diversity index

Species dominance index (C)

$$C = \sum_{i=1}^{n} \left(\frac{n_i}{N}\right)^2 \quad (13)$$

Note:

ni = density value at-i

N = total density

Horizontal Stand Structure

The configuration of the stand delineates the interplay between diameter categories and the tree count. Investigate the horizontal arrangement necessitates the acquisition of data encompassing both tree density and the classification based on tree diameter. This analytical process unveils nuanced details about the organization of the stand, shedding light on the spatial distribution and sizes of trees within it [14].

Correlation between NDVI Values with Total Species and Tree Density

The data on total species and tree density from ground checking were correlated with the NDVI values. The correlation between NDVI values and the total species and tree density was determined using Pearson Correlation. Pearson's correlation coefficient describes the closeness of the relationship between two or more variables [15].

Result and Discussion

Vegetation Density using NDVI in the MHSNP Traditional Zone

Estimation of vegetation density using NDVI (Figure 2) resulted in dividing the level of vegetation density into three classes with a range of NDVI values for each class. The classification of vegetation density refers to research [16], which are low, medium, and high densities with ranges of values of 0.15 to 0.25, 0.26 to 0.35 and 0.35 to 0.61, respectively. The obtained NDVI map is shown in Figure 2.

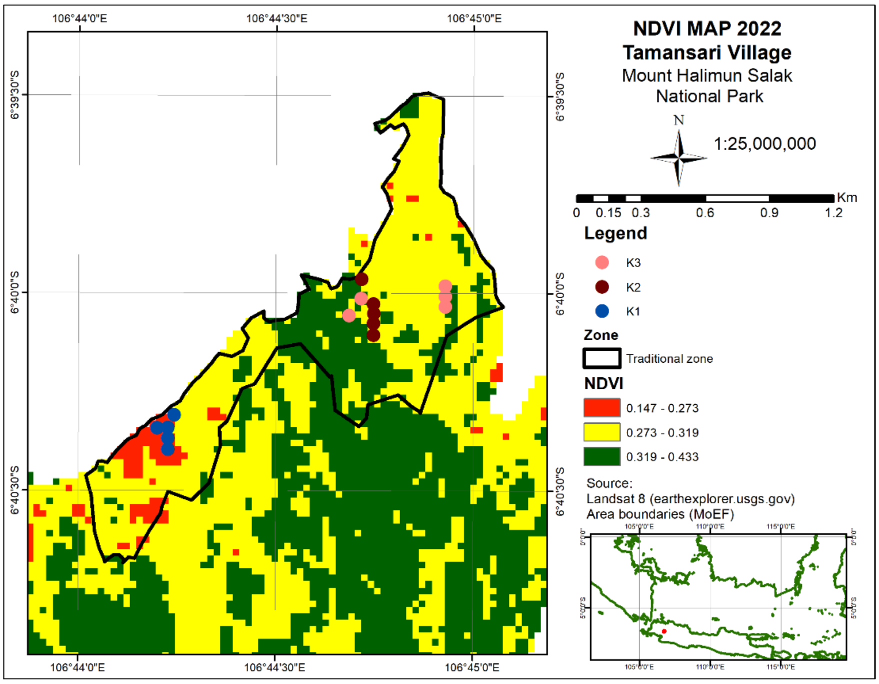

Figure 2. NDVI map in the MHSNP traditional zone.

Table 1 presents the NDVI values shown in Figure 2. The vegetation density in the MHSNP traditional zone, especially in Tamansari Village, has three density classes. The NDVI values obtained for each class showed different land conditions. Class 1 values ranged from 0.147 to 0.273 and had a low vegetation density. Class 2, which ranged from 0.273 to 0.319, had a medium vegetation density. Meanwhile, class 3 possessed a dense concentration, with a value of 0.319 to 0.433.

Table 1. NDVI values for each class in the MHSNP traditional zone.

Class	NDVI value	Vegetation density
1	0.147 – 0.273	Low
2	0.273 – 0.319	Medium
3	0.319 – 0.433	High

Diversity of Vegetation Types in the MHSNP Traditional Zone

The findings of the examination of vegetation life in the MHSNP traditional zone in each class showed a different number of species at each growth stage (Table 2). The number of species found at the tree level for classes 1, class 2 is 11, while class 3 was 6, 11, and 24, respectively. The highest level of understory growth was in class 2, which was 19, compared to classes 1 and 3, but the seedling level was not found in class 2.

Table 2. Number of species in the MHSNP traditional zone.

Level of growth	Number of species		
	Class 1	Class 2	Class 3
Understory	3	19	12
Seedling	1	0	1
Sapling	4	3	3
Pole	3	0	4
Tree	6	11	24
The total of all levels	15	33	37
Total of all three classes	60		

Table 2 shows that the growth level strata in classes 1 and 3 are complete. Meanwhile, Class 2 was incomplete due to the absence of species at the seedling and pole stages. The incomplete growth level strata in class 2 show that there is a problem with natural rejuvenation. This could be due to local people planting understory, which harvests faster than woody plant seedlings. The IVI is an index calculated in vegetation analysis that provides an overview of the influence or the function of a plant species within a botanical community [17]. The IVI values for each class are presented in Table 3.

Table 3. The three most significant IVI values in every class.

Level of growth	Class					
	1		2		3	
	Species name	IVI (%)	Species name	IVI (%)	Species name	IVI (%)
Understroy	*Seuseureuhan* (*Piper aduncum*)	99.39	*Poh-pohan* (*Pilea melastomoides*)	65.20	*Poh-pohan* (*Pilea melastomoides*)	81.09
	Babakoan (*Eupatorium sordidum*)	88.50	*Rumput jablai* (*Eleusine indica*)	26.63	*Pakurane* (*Selaginella sp.*)	18.15
	Harendong bulu (*Clidema hirta*)	12.10	*Seuseureuhan* (*Piper aduncum*)	14.89	*Jamarak* (*Setaria barbata*)	16.41
Seedling	*Ki sauheun* (*Orophea hexandra*)	200.00	-		*Kayu afrika* (*Maesopsis eminii*)	200.00
	-		-		-	
	-		-		-	
Sapling	*Harendong besar* (*Bellucia pentamera*)	106.67	*Rambutan* (*Nephelium lappaceum*)	66.67	*Menteng* (*Baccaurea racemosa*)	110.00
	Kayu afrika (*Maesopsis eminii*)	36.67	*Menteng* (*Baccaurea racemosa*)	66.67	*Damar* (*Agathis dammara*)	53.33
	Kopi (*Coffea canephora*)	28.33	*Suren* (*Toona sureni*)	66.67	*Harambai* (*Baccaurea motleyana*)	36.67
Pole	*Harendong besar* (*Bellucia pentamera*)	144.12	-		*Alpukat* (*Persea americana*)	171.54
	Ki copong (Cecropia peltata)	95.10	-		*Lame* (*Alstonia scholaris*)	43.85
	Mara (*Macaranga tanarius*)	60.78			*Kayu afrika* (*Maesopsis eminii*)	42.31
Tree	*Pinus* (*Pinus merkusii*)	195.74	*Pinus* (*Pinus merkusii*)	132.48	*Pinus* (*Pinus merkusii*)	81.74
	Benda (*Artocarpus elasticus*)	27.92	*Damar* (*Agathis dammara*)	49.83	*Suren* (*Toona sureni*)	42.32
	Mara (*Macaranga tanarius*)	23.55	*Rasamala* (*Altingia excelsa*)	33.00	*Menteng* (*Baccaurea racemosa*)	24.61

(-): not found

Table 3 displays the top three species with the highest IVI during each stage of growth. The seedling level in class 1 had only one type, *ki sauheun*, with an IVI value of 200%. Meanwhile, the main commodity, trees, is not found in Class 1 because this area is slightly steep, which makes it difficult for the community to plant so that local people do not plant in that area. Table 3 also lists the IVI values for Class 2. The highest IVI was in Class 2, which included pine trees (132.48%), followed by the saplings of *rambutan*, *menteng*, and *suren*, which had the same IVI value (66.67%). In addition, the understory level in class 2 includes plants cultivated by local people, such as *poh-pohan* species (*Pilea melastomoides*) with an IVI of 65.20%.

Table 3 shows that the highest IVI is in class 3, which is the level of *Kayu afrika* seedlings and the level of avocado poles with values of 200% and 110%, respectively. *Kayu afrika* is an invasive species. Furthermore, the high IVI value for *Kayu afrika* is because part of the MHSNP area was previously a *Perhutani* area for production purposes, where fast-growing species were planted, one of which was *Kayu afrika*. However, the MHSNP area has now become a conservation area, and logging is not permitted. The highest IVI value indicates that many local people plant or cultivate this species on agroforestry land in the traditional zone. This is in accordance with a previous study [18], which stated that the higher the IVI value of a plant, the more substantial the role or contribution of these specific plant types, such that these types of plants are more commonly planted by the community / farmers.

Table 4 shows the values of the vegetation diversity indices H', C, R, and E at each growth stage in the traditional GHSNP zone. Furthermore, the index value of species diversity (H') for all levels of growth in class 1 (low density) and class 2 (medium density) had a low category, while class 3, namely the high-density class, had a medium category at the tree level and low at the level of understory, seedlings, saplings, and poles. This suggest that the species diversity index within a community is constituted by a limited number of species [19]. The dominance index of the seedling level type in classes 1 and 3 shows a value of 1, which shows that the seedling plot is dominated by only one type.

Table 4. Vegetation diversity index values.

Level of growth	H'			C			R			E		
	K1	K2	K3	K1	K2	K3	K1	K2	K3	K1	K2	K3
Understory	0.74 (Rd)	1.65 (Rd)	1.35 (Rd)	0.50	0.30	0.43	0.38 (Rd)	2.96 (Rd)	1.76 (Rd)	0.67 (Ti)	0.56 (Sd)	0.54 (Sd)
Seedling	-	-	-	1.00	-	1.00	-	-	-	-	-	-
Sapling	0.98 (Rd)	1.10 (Rd)	1.01 (Rd)	0.49	0.33	0.39	1.21 (Rd)	1.82 (Rd)	1.12 (Rd)	0.71 (Ti)	1.00 (Ti)	0.92 (Ti)
Pole	1.01 (Rd)	-	1.33 (Rd)	0.39	-	0.28	1.12 (Rd)	-	1.86 (Rd)	0.92 (Ti)	-	0.96 (Ti)
Tree	1.09 (Rd)	1.37 (Rd)	2.50 (Sd)	0.50	0.40	0.13	1.59 (Rd)	2.03 (Rd)	5.03 (Ti)	0.61 (Ti)	0.57 (Sd)	0.79 (Ti)

H': Species diversity index, C: Species dominance index, R: Species richness index, E: Species evenness index, K1: Low vegetation density, K2: Medium vegetation density, K3: High vegetation density, Rd: Low, Sd: Medium, Ti: High

The species richness index (R) values for all growth stages in classes 1 and 2 were in the low category, whereas class 3 had a high category at the tree level and low at the understory, seedling, sapling, and pole levels. This species richness value (R) relates to the count of species identified at the tree level in Class 3 compared with the others [20]. Moreover, the species evenness index (E) values in the traditional zone showed medium and high categories (Table 4). The maximum E value was recorded at the sapling stage of class 2, while the minimum was identified at the understory level of class 3, but it was still in the moderate category. This shows that the traditional zone has species with a relatively equal or even distribution of each individual owing to the planting by the community in the traditional zone according to what the community needs [20].

Stand Structure in the MHSNP Traditional Zone

The horizontal stand structure describes the location of forest vegetation based on the relationship between the growth rate of the diameter class vegetation and the individual density per hectare [21]. The stand structure conditions in the traditional zone of the MHSNP are depicted in Figure 3. Figure 3 shows that the density of seedlings was lower than that of the saplings. However, at the pole and tree levels, it decreases. This indicated a balanced stand structure. The low seedling level is caused by the inhibition of seedling growth due to cleaning by the local community in preparation for planting understory, because the community prefers to plant understory that harvests faster; besides, it is profitable without waiting for a long time. Meanwhile, the low density of seedlings shows that the local community only plants or cultivates understory, such as *poh-pohan* species, and the local community does not plant forest plant species, such as pine and *suren*, so regeneration at the seedling level is very low. In addition, the highest density was obtained in the high-density class (Class 3), which reached a value of 1,658 ind/ha, whereas the lowest density was obtained in the medium density class (Class 2), which was 351 ind/ha. Agroforestry systems can cause modifications in the structure and composition of vegetation in the traditional zone of the MHSNP.

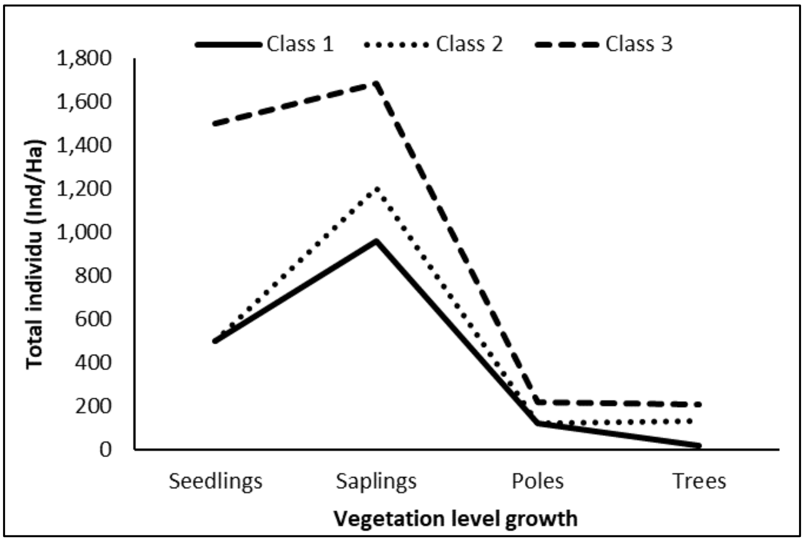

Figure 3. The stand structure in the traditional zone of MHSNP.

Correlation between NDVI Values with Total Species and Tree Density

Data on the total species, tree density (ind/ha), and NDVI values that fulfilled the assumptions of data normality were tested for Pearson correlation. The correlations between total species, tree density (ind/ha), and NDVI values are presented in Table 5. The total number of species had a positive correlation with NDVI values of 0.769 (very strong). This shows that the higher the total species, the higher the NDVI values. Tree density was positively correlated with an NDVI value of 0.576. This also shows that the higher the total species, the higher are the NDVI values. The research of Arnanto [22] also showed that NDVI with variations in vegetation type or tree stand density has a real relationship and a positive correlation. In other words, NDVI values from remote sensing can describe the total species and tree density in the traditional zone of the MHSNP.

Table 5. Pearson correlation between total species, tree density (ind/ha), and NDVI values.

Variable	Total species	Tree density (ind/ha)
Total species	-	-
Tree density (ind/ha)	0.533*	-
NDVI values	0.769**	0.576*

** The correlation achieves significance at the 0.01 threshold (two-tailed); * The correlation achieves significance at the 0.05 threshold (two-tailed)

Conclusion

The low vegetation density in the MHSNP traditional zone had an NDVI value of 0.147 to 0.273 (Class 1). Meanwhile, the medium density (class 2) had an NDVI value of 0.273 to 0.319. In addition, the high density (class 3) had an NDVI value of 0.319 to 0.433. The level of species diversity for all levels of growth in classes 1 and 2 was low, while class 3, namely the high-density class, had a moderate category at the tree level and low at the understory, seedling, sapling, and pole levels. Furthermore, the stand structure in the traditional zone of MHSNP has a lower density of seedlings than saplings, but it decreases at the pole and tree levels, which shows a balanced stand structure. The low seedling level is caused by the inhibition of seedling growth due to cleaning by the local community in preparation for planting and cultivation of understory, such as *poh-pohan* species, and less planting of forest plant species since they are considered to be harvesting faster and profitable without waiting for a long time for the local community. NDVI values were positively correlated with total species and tree density. The NDVI values from remote sensing can describe the total species and tree density in the traditional zone of the MHSNP.

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