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To cite this article: APP Hartoyo *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1145** 012011

Vegetation cover changes and species composition: preliminary results from agroforestry system in Gunung Halimun Salak National Park, Indonesia

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Abstract. As a mitigation target for Indonesia's Forestry and Other Land Use (FOLU) Net Sink 2030, Gunung Halimun Salak National Park (GHSNP) has a high potential. However, there is a lack of data on tree species composition and vegetation cover, particularly in the traditional zone (TZ). This study aims to estimate the vegetation cover of GHSNP in 2016, 2019, and 2022, as well as tree species composition in the TZ compared to the wilderness zone (WZ). This study used Sentinel-2 imagery and plot establishment for vegetation analysis in both zones. The most dominant class of vegetation cover in GHSNP from 2016 to 2022 is in class 5 which has highly dense vegetation. The large area class 5 increased by around 2.17% from 2016 to 2022. There were 17 species found in TZ and 24 species in WZ. Local communities are applying the traditional agroforestry of Poh-pohan (*Pilea trinervia*) as the main commodity and *Pinus merkusii* for the shade trees. *P. merkusii* and *Maesopsis eminii* are the most frequently found in TZ and WZ due to the former status of GHSNP as a production forest. Agroforestry systems can enhance biodiversity as a conservation effort and Indonesia's FOLU Net Sink 2030 actions.

Keywords: FOLU Net Sink 2030; traditional agroforestry; traditional zone; wilderness zone.

1. Introduction

Indonesia's Ministry of Forestry declared Gunung Halimun Salak with a total forest area of around 113,357 ha as a national park in 2013 [1]. In the Dutch colonial period (1979), Gunung Halimun has been declared a nature reserve by the Indonesian government (covering some 40.000 ha). Gunung Halimun Salak National Park (GHSNP) has changed its function to a conservation area from a production area based on decree Number 175/Kpts-II/2003. The previous management was *Perum Perhutani*. In 2016 GHSNP area is approximately 87,699 ha [2]. The administrative area of GHSNP includes Banten, Bogor, and Sukabumi Regencies. Conservation efforts have been increased for more than 50 years in the world through preserving and protecting biodiversity, biomass, water resources, and other natural values [3]. Most of the GHSNP area is classified into tropical mountain forests and it is the biggest in Java [4]. Van Steenis [5] classified GHSNP ecosystems based on altitude, specifically a collin zone (500-1000 asl), sub-montane zone (1000-1500 asl), and montane zone (1500-2400 asl). The dominant tree species in the collin zone of GHSNP are puspa (*Schima wallichii*), rasamala (*Altingia excelsa*), and saninten (*Castanopsis javanica*), while the dominant tree species in the montane zone of GHSNP are kibima (*Podocarpus blumei*), jamuju (*Dacrycarpus imbricartus*) and kiputri (*Podocarpus neriifolius*) [1]. Endangered species are existing in GHSNP, for example, Javan Hawk (*Spizeatus bartelsi*), Javan Leopard (*Panthera pardus*), and Javan Gibbon (*Hylobates moloch*). Considering those conditions, GHSNP can be a target to implement mitigation action for Indonesia's FOLU (Forestry and Other Land Use) Net Sink 2030. FOLU Net Sink 2030 is Indonesia's government goal in addressing the sequester level that is equal to/higher than the emission level of greenhouse gasses. The target net sinks in 2030 amount to 140 million tons of $CO_{2e.}$ This target can be achieved by monitoring forest cover area (e.g., remote sensing) and vegetation analysis as baseline data to consider the appropriate decisions in forest management.

On the other hand, JICA (2006) revealed that the GHSNP area decreased by 25% from 1989 to 2001. This report supported by [4] that explained GHSNP forest cover decreased from 1989 to 2003 with a deforestation rate of approximately 1.2-2.3% per year. The major factors are encroachment [7], illegal logging, industrial plantation, agricultural expansion, over-exploitation of natural resources, and tenurial conflicts [8]. The local community strongly depends on the GHSNP forest. Around 314 settlements stayed within GHSNP and 100,000 people depend on the GHSNP forest as their livelihood. They cultivated paddy, vegetables, and harvested forest products (e.g., fodder and edible plants). There are some traditional forest management systems in GHSNP, namely: i) protected forests for protection and no access for the community, ii) closed forests for protection, so the local community can harvest NTFPs, and iii) open forests for production aims such as paddy field as well as shifting cultivation [9]. However, the traditional system management did not exist anymore in most of the local communities in GHSNP. JICA [7] stated that in 2006, there were 68,113 poor households in GHSNP. Conservation efforts in GHSNP management need to synergize ecologically and socio-economic aspects. A forest monitoring system in GHSNP is crucially needed, such as using remote sensing technology that can be carried out accurately, effectively, and efficiently. An attribute to show forest health and cover can be seen from the greenness level of vegetation using the Normalized Difference Vegetation Index (NDVI).

NDVI is a numerical indicator using the visible light (RED) and near-infrared bands (NIR) of the electromagnetic spectrum to analyze remote sensing measurements in assessing the target observed, especially live green vegetation. Healthy vegetation will absorb visible light (RED) and reflects a greater proportion of near-infrared light (NIR). While unhealthy vegetation will reflect a higher visible light (RED) and a few near-infrared light (NIR). Besides estimating vegetation cover changes [10-12], NDVI can be used to estimate soil erosion and fire incidents indicators [13-14], land use/land cover changes (LULC), as well as indicators of vegetation health [15]. The vegetation index has long been used for vegetation cover change monitoring and has often been used to analyze the interaction between vegetation growth and climate at the landscape level, to help forest and land management, as well as to utilize the sustainability of forests. Besides that, this index can be used to investigate the impact of climate change and carbon stock in various vegetation types [21]. The most familiar vegetation indices for vegetation density monitoring is NDVI. Cunyong et al. [22] reported that NDVI is an indicator in estimating vegetation cover percentage in various topographical conditions in China.

Forest vegetation cover monitoring in GHSNP is strongly needed to assess forest quality status and decide the proper forest management in terms of achieving Indonesia's FOLU Net Sink 2030. A method to monitor GHSNP vegetation cover changes is through NDVI analysis. This method is rarely carried out in GHSNP, whereas the results can be obtained quickly, accurately, and cheaply. Furthermore, GHSNP has various zones, such as the core, wilderness, utilization, rehabilitation, cultural, special, and traditional [1]. The traditional zone (TZ) is built for the local communities around the forest to fulfill their subsistence needs by utilizing the forest [16]. The local communities are applying the traditional agroforestry of Poh-pohan (*Pilea trinervia*) as the main commodity and pine (*Pinus merkusii*) as the shade trees in TZ of GHSNP. Tree species composition study in this traditional agroforestry is limited. Based on this background, this study aims to estimate i) the vegetation cover of GHSNP in 2016, 2019, and 2022, also ii) tree species composition in the TZ compared to the wilderness zone (WZ). WZ is an area in the national park that can be used for the habitats/home ranges of wild animals to protect and support the breeding efforts of wild animals. This area has species diversity that is able to support the preservation of core and utilization zones [20].

2. Method

2.1 Study Site and Periods

The vegetation cover changes were studied in Gunung Halimun Salak National Park (GHSNP), West Java, Indonesia. Tree species composition was conducted in the traditional zone (TZ) and wilderness zone (WZ) of GHSNP that belong to the administrative area of Tamansari Village, Bogor Regency, West Java. This study started from June to August 2022.

GHSNP has a height between 500-2211 masl and an average annual rainfall between 4000-6000 mm/year. The average relative humidity in GHSNP is 88% with an air temperature is 31.5^{O}C [17]. GHSNP consists of natural forests, rubber plantations, mixed farms or agroforestry systems, tea gardens, rice fields, grass, shrub, and other land uses.

2.2 Tools and Materials

The tools and materials used were compasses, phi band, GPS, machete, ArcGIS, map area of GHSNP, and Sentinel-2 images of GHSNP in 2016, 2019 also 2022.

2.3 Research Procedure

1) Vegetation Cover Changes Analysis using NDVI in GHSNP

Sentinel-2 image selection used was an image that has less cloud cover. In this study area, a vegetation cover analysis was carried out using 2 Sentinel-2 images in the same year to cover the entire study area. Sentinel-2 images used were i) in 2016, specifically 28 August 2016 (Sentinel-2A MSIL 1C) and 7 October 2016 (Sentinel-2A MSIL 1C), ii) in 2019, specifically 24 July 2019 (Sentinel-2A MSIL 2A) and 8 August 2019 (Sentinel-2B MSIL 2A), and iii) in 2022, specifically 4 January 2022 (Sentinel-2B MSIL 2A) as well as 8 July 2022 (Sentinel-2B MSIL 2A).

Both images were processed by the mosaic process for each band. Furthermore, the analysis of land cover changes through the Normalized Difference Vegetation Index (NDVI) calculation method using Sentinel-2 imagery was carried out using the formula [28]:

$$\text{NDVI} = \frac{NIR - Red}{NIR + Red}$$

Where:

NDVI : Normalized Difference Vegetation Index
Red : Reflectance of the RED channel on channel 4 Sentinel-2 (RED channel spectral wavelength 650 to 680 nm)
NIR : Reflectance of the NIR channel on channel 8 Sentinel-2 (NIR channel 785 to 899 nm spectral wavelength)

Once the NDVI calculation is complete, the next step is to classify the NDVI imagery raster values using the reclass feature.

2) Plot Establishment in Traditional Zone and Wilderness Zone of GHSNP

Sampling plots were established in the traditional zone (TZ) and wilderness zone (WZ) of GHSNP based on the NDVI analysis results. From 5 classes of NDVI results in the whole area of GHSNP, we obtained 3 classes of NDVI in TZ and WZ of GHSNP. Hence, we only focused on 3 classes representing low dense, moderate-dense, and high-dense vegetation at each TZ and WZ. Each plot size was 50x50 m following [18] with sub-plot sizes 10 x 10 m, 5 x 5 m, and 2x2 m (Figure 1).

IOP Conf. Series: Earth and Environmental Science 1145 (2023) 012011 doi:10.1088/1755-1315/1145/1/012011

Figure 1. Plot sampling design

3) Tree Species Composition Measurement in the Traditional Zone and Wilderness Zone of GHSNP
Plots of 50 x 50 meters were set up to measure tree level, subplots of 10 x 10 meters were set up to measure pole level, subplots of 5 x 5 meters were set up to measure sapling level, and subplots of 2 x 2 meters were set up to measure seedlings and understorey. Using the formula developed by Mueller & Ellenberg [19], we calculated the important value index (IVI) for the purpose of determining the dominant species in an ecosystem. We compared species composition at each growth level in WZ and TZ descriptively.

3. Results And Discussions

3.1 Vegetation Cover Changes of Gunung Halimun Salak National Park Using NDVI

The NDVI value ranges from -1 to +1. A negative NDVI value indicates clouds and water, whereas a close to 0 value indicates bare soil and no green leaves. In GHSNP, the NDVI analysis identifies five categories of vegetation cover. Those are: (i) class 1 has NDVI values between -1 and 0.03. It denotes a non-vegetation area and a waterbody, (ii) class 2 has NDVI values between -0.03 and 0.15. It denotes very sparse vegetation, (iii) class 3 has NDVI values between 0.15 and 0.25. It indicates low vegetation density, iv) class 4 has NDVI values between 0.26 and 0.35. It denotes vegetation that is moderately dense, and v) class 5 has NDVI values between 0.35 and 1. It shows highly dense vegetation (Table 1).

The most dominant class of vegetation cover in GHSNP from 2016 to 2022 is in class 5 (highly dense vegetation). Table 1 shows the large area class 5 in 2016 is 83,012.67 ha and increases by around 2.22% in 2022. While the large area class 2 (very low-dense vegetation) in 2016 is 268.02 ha and increases by around 202.07% in 2022. The large area classes 3 and 4 in 2016 in order are 1,056.17 ha and 3,348.49 ha then decrease by around 23.84% and 63.50%. Dynamic vegetation cover changes that are shown by NDVI values are mainly caused by human population pressure and economic demands through human activities [23]. It is supported by Dunggio & Gunawan [24] that explained dynamic forest area status in national park depend on the local community welfare.

Table 1 Vegetation cover changes in GHSNP

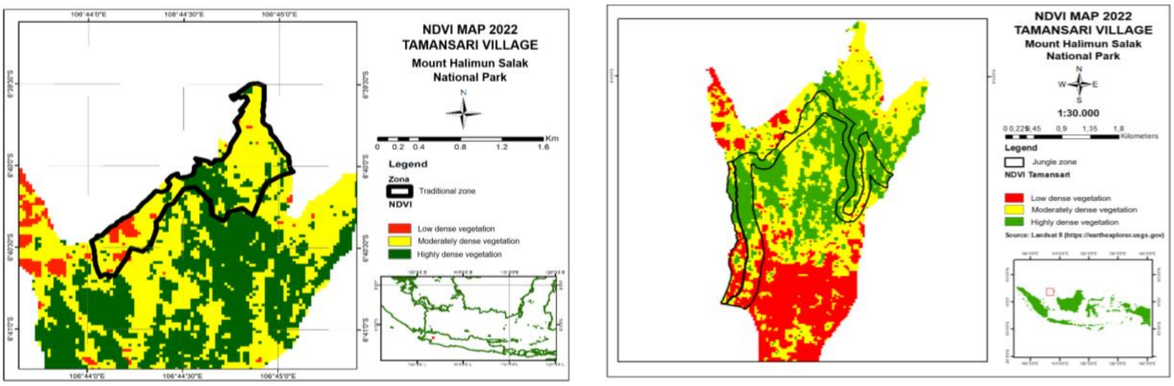
Class	NDVI value	Description	2016		2019		2022	
			Large (ha)	Proportion (%)	Large (ha)	Proportion (%)	Large (ha)	Proportion (%)
1	-1 to -0.03	Waterbody and non-vegetation area	12.40	0.01	34.87	0.04	4.98	0.01
2	-0.03 to 0.15	Very low dense vegetation	268.02	0.31	119.66	0.14	809.60	0.92
3	0.15 to 0.25	Low dense vegetation	1,056.17	1.20	234.51	0.27	804.41	0.92
4	0.26 to 0.35	Moderately dense vegetation	3,348.49	3.82	585.92	0.67	1,222.15	1.39

5	0.35 to 1	Highly dense vegetation	83,012.67	94.66	86,722.79	98.89	84,856.62	96.76
Total			87,697.76	100.00	87,697.76	100.00	87,697.76	100.00

Many local community activities are conducted around GHSNP. GHSNP land use is categorized into land farming and mixed shrub as large as 3,137.53 ha, paddy field as large as 2,578.04 ha, dry land farming as large as 628.22 ha, and housing area as large as 75.88 ha. According to [27], vegetation cover conditions in GHSNP can be influenced by the success of forest ecosystem rehabilitation programs. GHSNP has forest ecosystem rehabilitation programs, namely the expansion of forest rehabilitation in conservation areas, forest restoration-based community and private, as well as forest tree adoption.

3.2 Comparison of Tree Species Composition in the Agroforestry System of the Traditional Zone with Wilderness Zone of GHSNP

In the traditional and wilderness zones of Gunung Halimun Salak National Park (GHSNP) in Tamansari Village, normalized difference vegetation index (NDVI) analysis revealed only three classes of vegetation cover: i) class 1 has NDVI values between 0.15 and 0.27, which indicates low density, ii) class 2 has NDVI values between 0.27 and 0.32, which indicates moderate density, and iii) class 3 has NDVI values between 0.32 and 0.43, which indicates high density (Figure 2). In order to assess the composition of the tree species in both the traditional zone and the wilderness zone of GHSNP, sampling plots for each class of vegetation were established.



(a) (b)

Figure 2 NDVI Map in the traditional zone (a) and wilderness zone (b) of GHSNP

Vegetation analysis results showed there were 17 species found in TZ and 24 species in WZ. At the understorey level showed that in TZ class 1 was dominated by the *Piper aduncum* with an IVI value of 200%, while in TZ class 2 was dominated by the *Eleusine indica* (IVI of 86.67%), and in TZ class 3 was dominated by *Piper aduncum* (IVI of 68.12%) as well *as Selaginella* sp. (IVI of 68.12%). Additionally, at the understorey level in WZ class 1 was dominated by *Cyperus rotundus* (IVI of 88.83), in WZ class II was dominated by *Pilea trinervia* (IVI of 54.67%), and in WZ class 3 was dominated by *Ageratum conyzoides* (IVI of 100%). Detail important value index at the understorey level is presented in Table 2.

Table 2 Important value index at the understorey level

Species	IVI (%)					
	Traditional zone			Wilderness zone		
	C1	C2	C3	C1	C2	C3
Ageratum conyzoides	-	-	-	-	-	100.00
Calamus rotang	-	-	-	29.26	-	-
Cheilocostus speciosus	-	-	-	-	18.13	-
Clidemia hirta	-	-	-	-	29.67	-
Curculigo cavitulata	-	-	-	-	-	21.82

Cycas sp.	-	-	-	-	18.13	-
Cyperus rotundus	-	-	-	88.83	-	-
Deparia petersenii	-	26.54	-	-	-	-
Diplazium esculeutum	-	-	-	-	-	34.55
Eleusine indica	-	86.67	-	-	-	-
Hydrocotyle splendens	-	-	-	-	18.13	-
Mikania micrantha	-	-	-	39.89	-	-
Musa troglodytarum	-	-	-	-	43.13	-
Pandanus amaryllifolius	-	27.19	-	-	-	-
Piper aduncum	200	29.80	68.12	-	-	-
Pilea trinervia	-	-	-	-	72.80	-
Schettlera aromatica	-	-	-	-	-	21.82
Selaginella sp.	-	-	68.12	-	-	21.82
Setaria barbata	-	-	63.77	-	-	-
Stenochlaena palustris	-	-	-	42.02	-	-

C1: class 1, C2: class 2, C3: class 3, (-): no found

At the seedling level, a species found in TZ class 1 was *Orophea hexaandra* (IVI of 200%) and a species found in TZ class 3 was *Maesopsis eminii* (IVI of 200%). In WZ class 1 was dominated by *Calliandra calothyrsus* (IVI of 200%), and WZ class 2 was also dominated by *Calliandra calothyrsus* (IVI of 75.64%). In WZ class 3 did not find any seedlings. Detail important value index for seedlings is presented in Table 3.

Table 3 Important value index at the seedlings level

Species	**IVI (%)**					
	Traditional zone			**Wilderness zone**		
	C1	**C2**	**C3**	**C1**	**C2**	**C3**
Calliandra calothyrsus	-	-	-	200	75.64	-
Dendrocnide stimulans	-	-	-	-	71.79	-
Maesopsis eminii	-	-	200	-	52.56	-
Orophea hexandra	200	-	-	-	-	-

C1: class 1, C2: class 2, C3: class 3, (-): no found

Vegetation analysis at the sapling level resulted that a species found in TZ class 1 and class 2 in order was *Bellucia axinanthera* (IVI of 200%) and *Nephelium lappaceum* (IVI of 200%). In TZ class 3 was dominated by *Agathis dammara* (IVI of 116.67%). The dominant species in WZ class 1 and class 2 was *Calliandra calothyrsus* with IVI in order 200% and 112.5%. In WZ class 3 was also dominated by *Calliandra calothyrsus* (IVI of 200%) (Table 4).

Table 4 Important value index at the saplings level

Species	**IVI (%)**					
	Traditional zone			**Wilderness zone**		
	C1	**C2**	**C3**	**C1**	**C2**	**C3**
Agathis dammara	-	-	116.67	-	-	-
Baccaurea racemosa	-	-	83.33	-	-	-
Bellucia axinanthera	200	-	-	-	-	-
Calliandra calothyrsus	-	-	-	200	112.50	200
Dendrocnide stimulans	-	-	-		87.50	-
Nephelium lappaceum	-	200	-		-	-

C1: class 1, C2: class 2, C3: class 3, (-): no found

A species found in TZ class 1 at the pole level was *Cecropia peltata* (IVI of 200%), and in TZ class 3 was dominated by *Persea americana* (IVI of 200%). In WZ class 1 was dominated by *Calliandra calothyrsus* (IVI of 200%), in WZ class 2 was dominated by *Maesopsis eminii* (IVI of 200%), while in WZ class 3 was dominated by *Baccaurea motleyana* (IVI of 200%) (Table 5).

Table 5 Important value index at the poles level

Species	IVI (%)					
	Traditional zone			Wilderness zone		
	C1	C2	C3	C1	C2	C3
Baccaurea motleyana	-	-	-	-	-	300
Calliandra calothyrsus	-	-	-	300	-	-
Cecropia peltata	300	-	-	-	-	-
Maesopsis eminii	-	-	-	-	300	-
Persea americana	-	-	300	-	-	-

C1: class 1, C2: class 2, C3: class 3, (-): no found

The TZ class 1 at the tree level was dominated by *Pinus merkusii* (IVI of 205,72%), TZ class 2 was dominated by *Pinus merkusii* (IVI of 198.67%), while in TZ class 3 was dominated by *Pinus merkusii* (IVI of 111,11%). In WZ class 1 was dominated by *Maesopsis eminii* (IVI of 221.66%), in WZ class 2 was dominated by *Maesopsis eminii* (IVI of 238.43%) and in WZ class 3 was dominated by *Maesopsis eminii* (IVI of 107.67%) (Table 6). Pine (*Pinus merkusii*), umbrella tree (*Maesopsis eminii*), and damar (*Agathis dammara*) are the dominant species in the conservation area of GHSNP due to the former status of GHSNP as a production forest. The local communities also use those species for shading *Pilea trinervia*. However, those species are the exotic plants in the national park [25] that can be a threat to indigenous species [26].

Table 6 Important value index at the level of the trees

Species	IVI (%)					
	Traditional zone			Wilderness zone		
	C1	C2	C3	C1	C2	C3
Agathis dammara	-	57.08	-	-	-	-
Artocarpus heterophyllus	-	-	20.79	-	-	-
Baccaurea racemosa	-	-	38.91	-	-	-
Dracontomelon dao	-	-	-	-	-	31.81
Maesopsis eminii	94.28	44.25	-	221.66	238.43	107.67
Paraserianthes falcataria	-	-	21.74	-	-	-
Persea americana	-	-	27.23	-	-	-
Pinus merkusii	205.72	198.67	111.11	-	-	-
Schima wallichii	-	-	-	-	-	64.81
Styrax benzoin	-	-	-	78.34	-	-
Swietenia mahagoni	-	-	-	-	-	34.64
Toona sureni	-	-	80.22	-	-	-
Trema orientalis	-	-	-	-	61.57	61.08

C1: class 1, C2: class 2, C3: class 3, (-): no found

4. Conclusions

The most dominant class of vegetation cover in GHSNP from 2016 to 2022 is in class 5 which has highly dense vegetation. The large area class 5 in 2016 is 83,012.67 ha and increases by around 2.17% in 2022. There were 17 species found in TZ and 24 species in WZ. Local communities are applying the traditional agroforestry of Poh-pohan (*Pilea trinervia*) as the main commodity and pine (*Pinus merkusii*) as the shade trees. Pine (*Pinus merkusii*) and umbrella tree (*Maesopsis eminii*) are the dominant species in the conservation area of GHSNP due to the former status of GHSNP as a production forest. The local communities also use those species for shading *Pilea trinervia*. Agroforestry systems can enhance biodiversity as a part of conservation and Indonesia's FOLU Net Sink 2030 actions.

Acknowledgment
The author thank the Directorate of Research, Technology, and Higher Education, the Indonesia Ministry of Education and Cultural for the funding through the basic research scheme, specifically the young lecturer research program in 2022, LPPM-IPB, Gunung Halimun Salak National Park and Gunung Salak 1 Resort Manager, as well as the villagers in Tamansari Village, Bogor, West Java.

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