

VEGETATION CHARACTERISTICS AND CARBON STOCKS AFTER EARTHQUAKE IN FOREST FOR SPECIFIC PURPOSE (KHDTK) SENARU (Karakteristik Vegetasi dan Cadangan Karbon Pasca Gempa Bumi di KHDTK Senaru)

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Article info:	ABSTRACT
Keywords: Carbon stock, earthquake, Senaru, vegetation cover	Kawasan Hutan Dengan Tujuan Khusus (KHDTK) or Forest for Specific Purposes in Senaru is a forest area designated for educational purposes. This study aims to assess ecological changes (i.e., vegetation cover, vegetation structure and diversity, and carbon storage) in KHDTK Senaru during three-time scales, namely in 2013 and in 2018; before and after the earthquake. Data were collected from 30 permanent quadratic plots, systematically distributed in these three different time scales. The vegetation cover results show a decreasing vegetation cover in the dense class but increasing in middle and sparse density classes. Changes in vegetation structure and diversity are noticeable at all regeneration stages, while the carbon storage changes at each time scale. This study indicates that disturbance due to the earthquake has minimal effect on the species diversity than management practices. Therefore, we recommend that the manager or forest users to consider planting more species to increase diversity, improve ecosystem resiliency, prevent damage expansion, and decrease the ecological function of KHDTK Senaru.
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I. INTRODUCTION

An earthquake is considered a natural disaster when its adverse impacts affect human beings directly or indirectly. However, these impacts can be positive as well as harmful. Examples of positive impacts are increased solidarity, cooperation, and tolerance. Simultaneously, negative impacts can occur in the material, physical, environmental and psychological disadvantages (Koresawa, 2009).

The earthquakes in Lombok Island occurring around August to September 2018 have impacted not only people but also forest resources. Based on the information from BPBD NTB in 2018, BNPB has recorded 214 infrastructures such as bridges, roads, bus terminals, docks, and irrigation and dams were

damaged and affected by disasters. The number of damaged houses reached 83,392 units. For schools, the number of damaged and affected reached 1,194 units. This earthquake also damaged 321 health facilities and worship places, with 630 mosques, 461 prayer rooms, one church in Mataram, one Buddhist monastery in North Lombok, and 50 Hindu temples, mostly in West Lombok (Pebrianto, Akhmad, & Hidayat, 2018). The worst impacted area by the earthquakes was mostly in North Lombok District. Loss of housings, mainly stone and cement-based building around the forest area, has inflicted severe trauma, which then drove the local people to rebuild their houses using timber and bamboos.

Senaru, a village in Northern Lombok located adjacent to the northern

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part of the Lombok forest area, was severely damaged by the 2018 earthquake. The 2018 earthquake destroyed almost 90% of the buildings in the Senaru region. The local people lost their primary source of income, which was mostly from tourism and agricultural activities. Both forest and agricultural lands suffered structural damage as they were converted into temporary settlements for the earthquake victims. Just a few months after the major earthquake, forest areas became the primary target for timber provision to fulfill the need for rebuilding houses. The local people observed that timber-based buildings such as the Senaru Customary Houses were more resilient.

Kawasan Hutan dengan Tujuan Khusus (KHDTK) or Forest with Specific Purpose in Senaru is a forest area designated for educational purposes. The area, managed by the University of Mataram in the Senaru region, is close to the local people's settlement severely affected by the earthquake. The University of Mataram, in collaboration with local communities, has planted in HDTK Senaru using an agroforestry system that combines woody vegetation and multipurpose trees (such as fruit trees) since 1996/1997. This was conducted after the forest had previously been depleted due to logging by the industrial forest company (*Hutan Tanaman Industri*). Then, the Senaru forest area became KHDTK and was managed by the University of Mataram in 2004.

Furthermore, KHDTK Senaru collaborated with 167 farmers and managed about 125 Ha of KHDTK Forest areas. It has also made the KHDTK Senaru vulnerable to encroachment. Open patches appeared in some areas of KHDTK Senaru after the earthquake in 2018, and it can be assumed that vegetation cover and diversity were disturbed and changed substantially. Managers found that a landslide caused open patches due to a natural earthquake movement and illegal logging conducted

by the community since they needed timber for emergency shade or house. Andari, Herlina, & Yamika (2018) strengthened that vegetation cover changes will significantly affect the ecological, economic, and social aspects. Ecologically, changes in vegetation cover will affect the CO₂ absorption process, leading to microclimate changes. Economically, if the local people depend on the vegetation for their livelihood, changes in vegetation cover may imply changes in their income and, lastly, may trigger the social aspect.

Furthermore, it is essential to carry out this study relating to changes in vegetation covers, diversity, and carbon storage to get the real condition and information. In this way, the KHDTK Senaru managers can develop new policies and scenarios after the earthquake to overcome problems and prevent the expansion of changes caused by earthquakes directly or anthropogenic activities and decrease the ecological function of KHDTK Senaru. Therefore, the objectives of this study are to assess (1) changes in vegetation cover using NDVI Method in Arc GIS 10.3 tools, (2) vegetation diversity using IVI, Species Diversity Index (Shannon-Weiner H'), Species Richness Index (d Margalef) and Species Evenness index (Pielou E') and (3) changes in carbon storage before and after the earthquake using the allometric equation in KHDTK Senaru.

II. MATERIALS AND METHODS

A. Study Area

This research was conducted in the Forest Area for the Specific Purpose of Senaru from October 2018 to February 2019. Administratively, it is located in Senaru Village, Bayan Subdistrict, North Lombok District, West Nusa Tenggara Province. Geographically, KHDTK Senaru is located between 08° 18' 08"- 08° 21' 07" South and 116° 22' 41"- 116° 25' 41" East with an area of 225.7 Ha (Figure 1).

B. Material

Some of the equipment used in this study consisted of (i) handheld GPS for navigating the system of object location, (ii) hagameter for measuring tree height, (iii) Phi band for measuring tree diameter at the breast height (1.3 m), or 20 cm above the buttress, (iv) compass and rope for setting plot angle and plot area, (v) analytic scales for measuring the wet (fresh) weight of soils, litter and understory, the oven-dry weight of forest litter and understory samples, and air dry weight of soil samples, (vi) oven for drying forest litter and understory samples, and (vii) plastic bags for storing the soils, forest litter, and understory samples. For data analysis, we used a computer with Excel Programme and Arc GIS 10.3. The materials we used in the analysis included vegetation, forest litter, and understory vegetation in 2018 before and after the earthquake. For comparison, we used secondary data taken from similar plots in 2013 (Idris, Latifah, Mahakam, Wahyuningsih, & Ningsih, 2013).

C. Data Collection

Data were collected in 2013 and 2018 (before and after the earthquake)

from 30 permanent quadratic plots distributed systematically throughout the area with random selection for the first plot (Kusmana, 2017), as seen in Figure 2.

Vegetation cover changes were detected through remote sensing using satellite imagery with the Normalized Difference Vegetation Index (NDVI) analysis method in Arc GIS 10.3 after the managers found some open areas inside KHDTK Senaru after the earthquake. A field survey was needed to assess the changing of vegetation diversity and carbon storage.

The number of 30 plots with the size of 20 m x 20 m for tree stage (diameter at breast height (dbh) \geq 20 cm) observation, 10 m x 10 m for pole stage (dbh 10-20 cm) observation, 5 m x 5 m for sapling stage (dbh < 10 cm and height > 1.5 m) observation, and 2 m x 2 m for seedling stage (height < 1.5 m), litter, understory vegetation, and soil sample observation comply with the standard set out in the Indonesia National Standard (SNI 7724, 2011). This is also consistent with Kusmana (2017) and Tahura et al. (2014) (Figure 3).

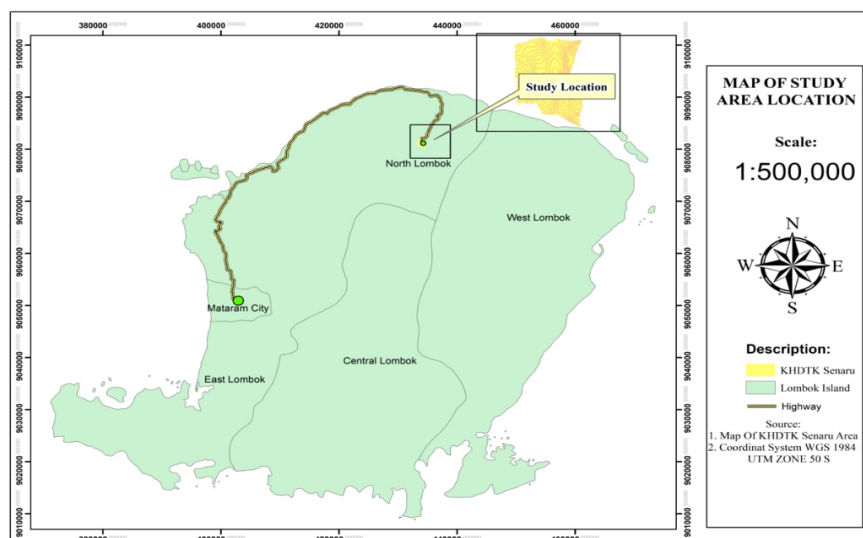


Figure 1. Map of KHDTK Senaru Area

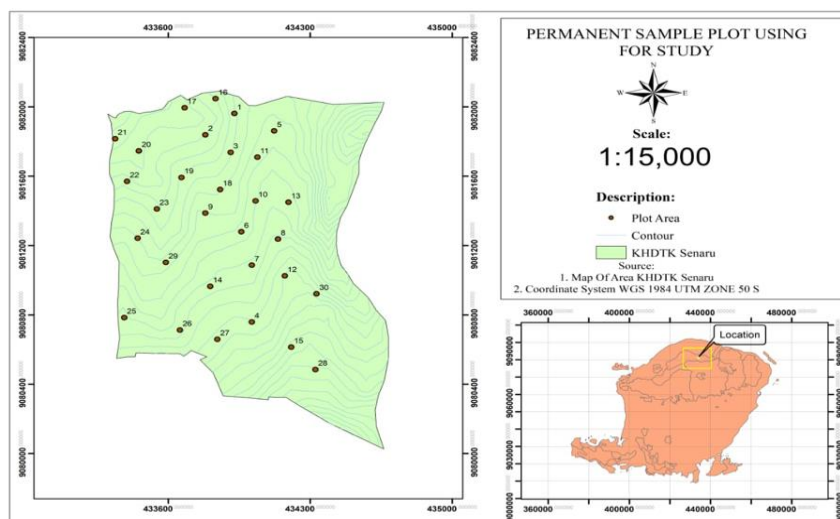
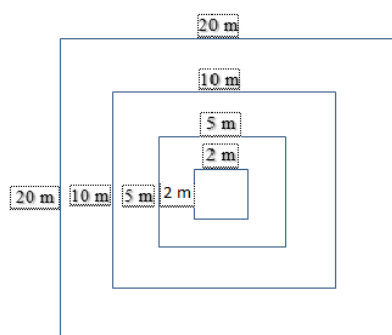


Figure 2. Systematic Distribution of Sample Plots



Remarks:

- Plot 20 m x 20 m = trees stage observation
- Subplot 10 m x 10 m = pole stage observation
- Subplot 5 m x 5 m = sapling stage observation
- Subplot 2 m x 2 m = seedling stage, litter, understorey vegetation and soil observation.

Figure 3. Vegetation analysis plot

From the sub-plot of 2 m x 2 m, we collected litter materials and understorey vegetation. Furthermore, understorey vegetation materials were cut using a knife or scissors, and they were put in a plastic bag. Simultaneously, we took soil sampling at each corner and the center of the 2 x 2 m plot using ring soil with a length of 5 cm and 10 cm with a diameter of 5 cm. The depths of soil sampling ranged from 0-5 cm, 5-10 cm, 10-20 cm, and 20-30 cm.

The variable data collected were tree diameter and height, the number of each tree species from various growth phases (seedling, sapling, pole, and tree), understorey vegetation, litter, and soil samples material. Data on the type and the amount of vegetation and diameter were

collected based on the parameter for calculating the value of IVI (Important Value Index) and diversity values (BSN, 2014).

D. Data Analysis

We used Arc GIS 10.3 tools with satellite imageries materials such as the Landsat 5 and Landsat 8 to monitor and analyze vegetation cover changes (Tampubolon & Yanti, 2015; Ashazy & Cahyono, 2013).

The changes in vegetation diversity were analyzed using the Important Value Index (IVI), Shannon-Weinner Species Diversity Index (H'), Margalef Species Richness Index (R'), and Pielou Species Evenness Index (E') (Samsodin, Heriyanto, & Endro, 2010; Tahura et al.,

2014; Nirwana, Hiola, & Karim, 2017; Kusmana, 2017; Rozak, Sri, Zaenal, Endah, & Didik, 2020). According to Nirwana et al. (2017) and Species Richness Index (R')—defined as the number of species in a specific area, which is categorized as low at $R' < 3.5$, moderate at $3.5 < R' < 5$, and high at > 5 . Meanwhile Species Evenness Index (E') is categorized as low at $0 < 0.3$, moderate at $0.3 < 0.6$ and high at > 0.6 , and Species Diversity Index (H') is categorized as low at < 1 , moderate at $1 < H' < 3$ and high at $H' > 3$.

The above-ground biomass carbon storage was analyzed using an allometric equation (Hairiah, 2018; Agus, Hairiah, Mulyani, & Centre, 2011), and carbon stored in the soil. It was determined by multiplying the soil's depth by the density of the soil using Excel software and the percentage of C-organic obtained from laboratory measurements using the spectrophotometer method based on BSN (2014) and SNI 7724 (2011).

The standard deviation (Sd) and mean (dR) of carbon storage differences between 2013 and 2018 were used to verify the changes. In this research, the standard deviation used in cluster determination was $(\pm Sd + dR)$. Sampling unit (plot) is considered as increasing if $(d_0 \geq Sd + dR)$, decreasing if $(d_0 \leq -Sd + dR)$ and steady if $(-Sd + dR \leq d_0 \leq Sd + dR)$ (Simon, 2007).

III. RESULTS AND DISCUSSION

A. Changes in Land Cover

The management scenarios, land area, and vegetation density significantly influenced the vegetation cover. Vegetation cover in one area has an impact on carbon sequestration in the area. The densely covered area sequesters a tremendous amount of carbon. If the vegetation cover is sparse, the carbon storage is also low. Arifanti, Dharmawan, & Wicaksono (2014) stated that the primary forest with dense vegetation cover has higher biomass and carbon

storage than sparse vegetation cover. Therefore, the denser the vegetation cover, the bigger the carbon storage it has. Based on the Landsat imagery analysis, the moderate vegetation cover dominated KHDTK Senaru with 122.46 Ha or around 54.26% of the total area of KHDTK Senaru in 2013. From the whole area of the KHDTK Senaru, around 94.86 Ha (42.03%) was very densely vegetated, while 8.37 Ha (3.71%) was sparsely vegetated. In 2018 before the earthquake, there was a decrease of 3.57% area with very dense vegetation. Meanwhile, an increase was observed for moderately and sparsely vegetated by 2.38% and 1.19%, respectively, compared to the 2013's condition. A further decrease in the total area was recorded for the very dense and moderate categories, around 1.74% and 2.06%, respectively, before the earthquake. Meanwhile, the sparse category area increased by 3.79% due to changes in dense and moderate areas.

Soil stability and cohesiveness are considered to have contributed to the changes in vegetation cover. In the very dense category, the vegetation cover decrease is due to soil structure aggregate instability, leading to reduced soil organic matter. In contrast, there was an increase in soil organic matter that affected the soil aggregate stability in areas with moderately and sparsely vegetated categories. Siringoringo (2014) suggested that the increase in soil organic matter and soil biota supports pedological development (soil formation, characteristics, and distribution), which contributes to soil stabilization from destructive disturbance, creating lanes for a higher infiltration rate. Besides, soil organic matter determines biological activities that significantly influence available water capacity, gas exchange, root growth, and nutrients stability (Hairiah, 2018; Quesada et al., 2019). The land cover changes resulted from tectonic plate movements that directly affected the vegetation community dynamic in

KHDTK Senaru. The size of the KHDTK Senaru area disturbed by earthquakes was 8.55 Ha or 3.78% of all areas, and there were 4 (four) plots, namely plots 13, 18, 28, and 29 (totally 0.16 Ha) were also disturbed. It is also emphasized by Pugnaire et al. (2019), who stated that earthquakes could cause changes in water moisture regime and temperature, and forest species succession with the diversity in the biomass quantity and quality returned to the soil. Earthquakes can also change the canopy cover, causing soil erosion and influencing soil carbon at the surface (Song et al., 2019). Figures 4 and 5 present the vegetation map cover changes in KHDTK Senaru and changes in vegetation KHDTK Senaru.

B. Changes in Vegetation Diversity

Vegetation diversity is the total number of species that occupy a particular niche characterized by a wealth of life forms, structures, and floristic periodicity combined with the land cover that forms the community. Based on observation results, we found 24 vegetation species

(14 trees, 12 poles, eight saplings, and eight seedlings) and nine understory vegetation species in the KHDTK Senaru in 2018, after the earthquake. Based on 2013 data, there were 32 vegetation species found (19 trees, 17 poles, eight saplings, and ten seedlings). However, the study did not identify the understory vegetation species. It took all understory vegetation as samples for calculating the carbon storage. The vegetation composition from 2013 to 2018 and after the earthquake in 2018 follows the general tropical forest vegetation patterns, and the stratification is still complete. According to Indriyanto (2008), a tropical forest comprises five strata: understory, seedling, sapling, pole, and tree. This view is also supported by Pamoengkas & Zamzam (2017), who stated that the complexity of natural regeneration availability in tropical forests includes seedlings, saplings, poles, and tree reserves. Figures 6 to 9 present the vegetation composition changes in the sample plots.

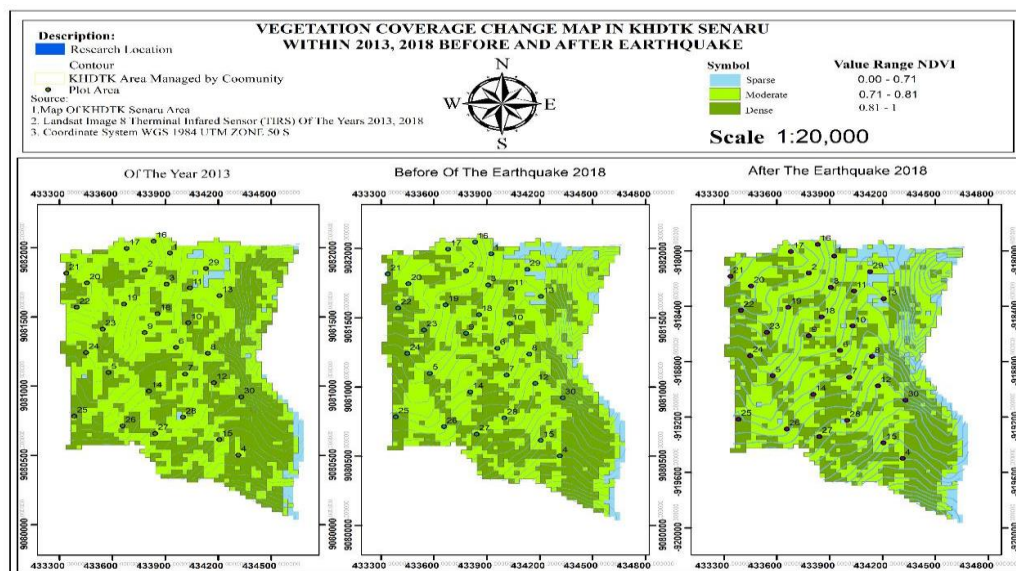


Figure 4. Map of Changes in Vegetation Cover in KHDTK Senaru from 2013 to 2018 (before and after Earthquake)

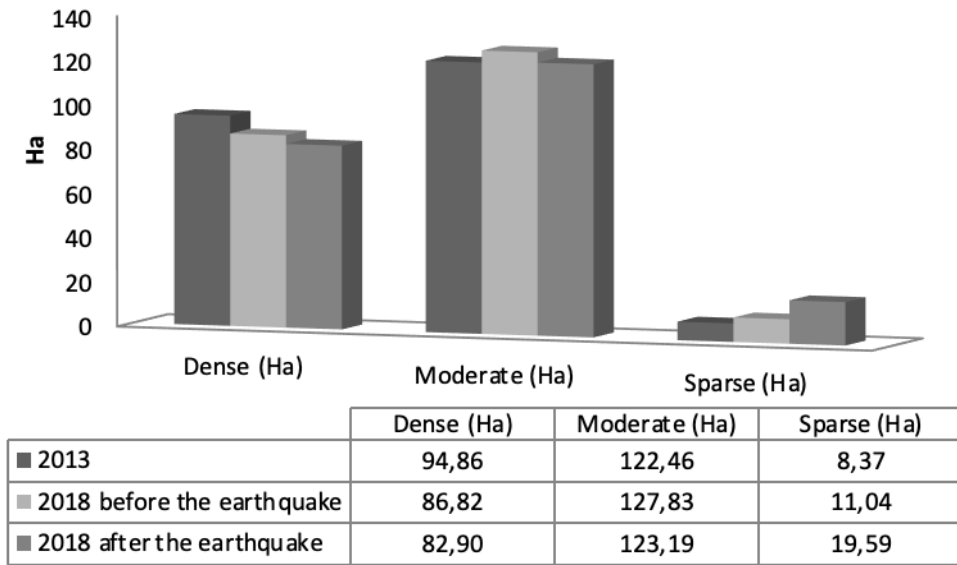
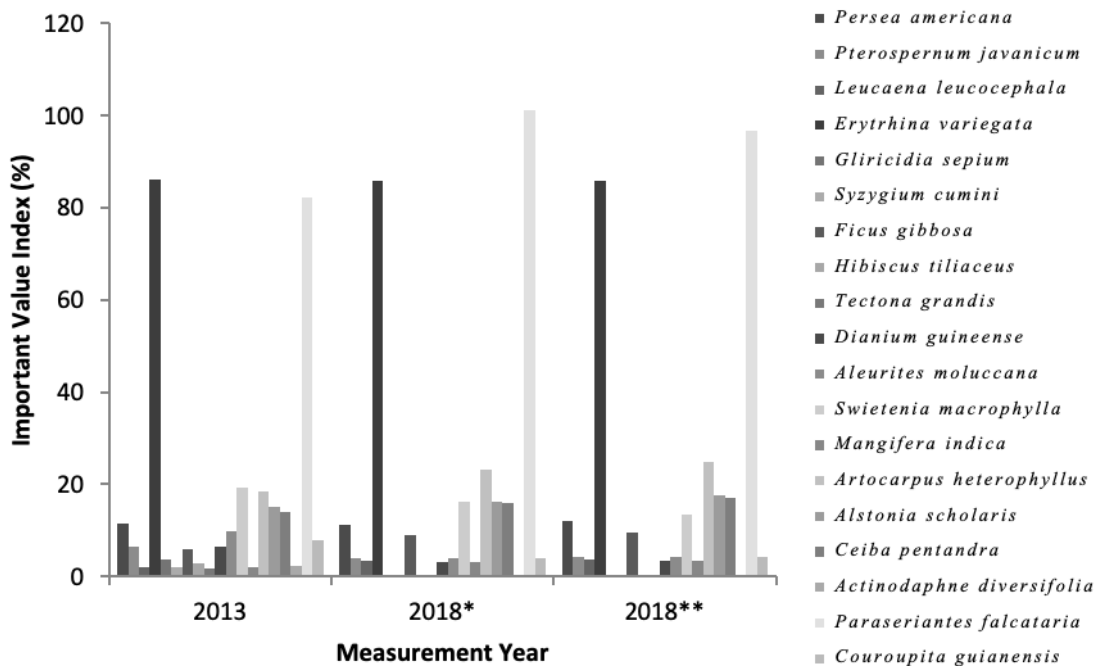


Figure 5. Changes in Vegetation Cover in KHDTK Senaru

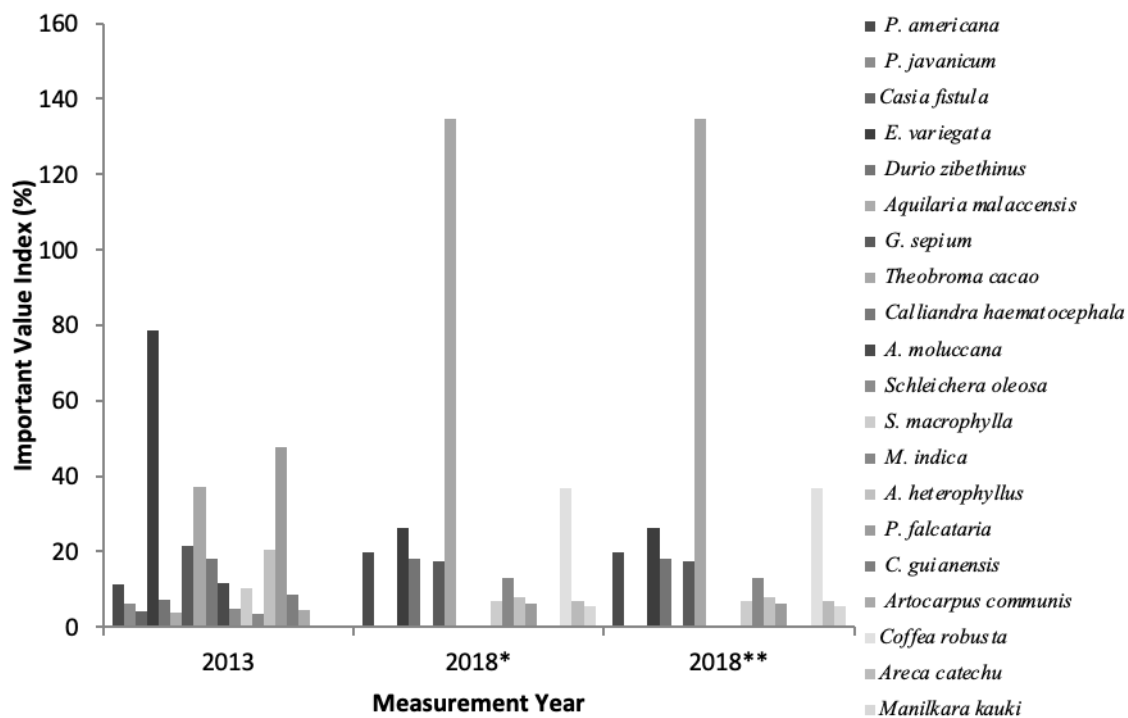
Importance Value Index (IVI) denotes how dominant a species is in a given forested area. The higher the index, the more dominant or important the species are (Mueller-Dombois &

Elenberg, 1975). Figure 6-9 shows the IVI for each level at three different time scales (2013, 2018 before the earthquake, and 2018 after the earthquake).



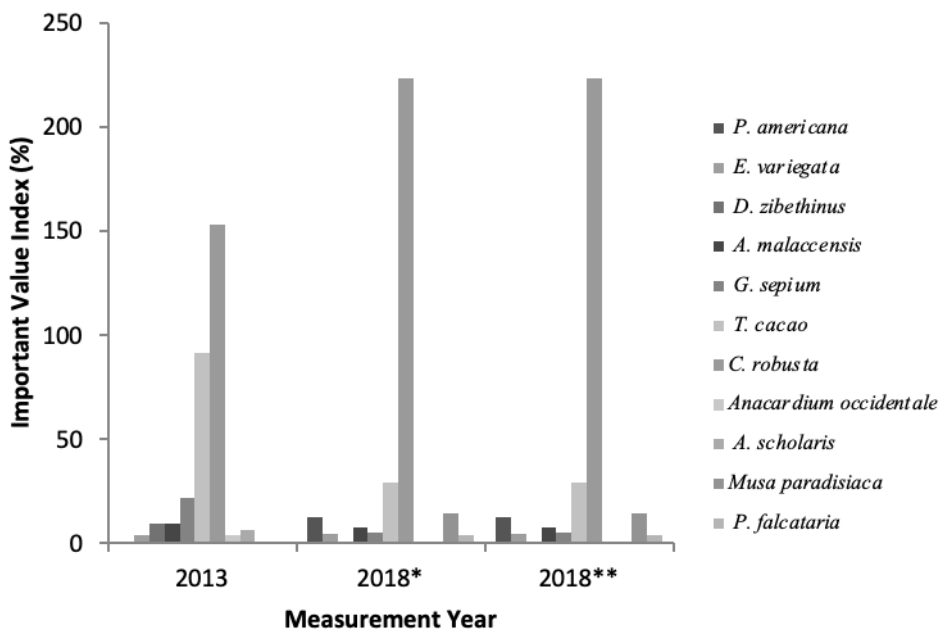
*) 2018 before earthquake and **) after the earthquake

Figure 6. Changes in Vegetation Composition based on IVI at Tree Level from 2013 to 2018



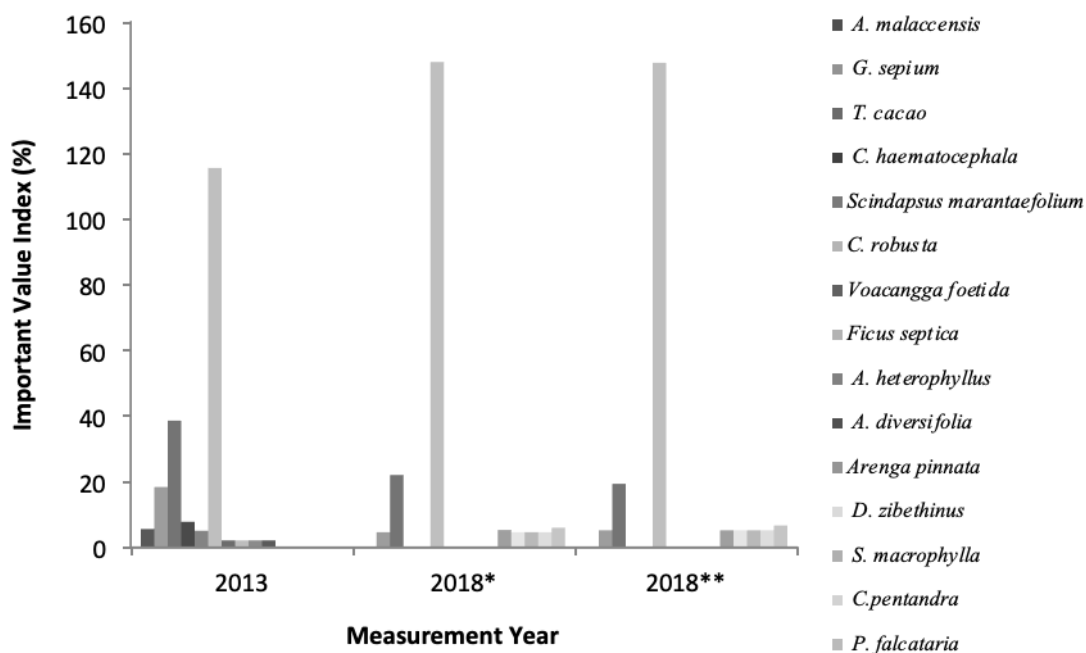
*) 2018 before earthquake and **) after the earthquake

Figure 7. Changes in Vegetation Composition based on IVI at Pole Level from 2013 to 2018



*) 2018 before earthquake and **) after the earthquake

Figure 8. Changes in Vegetation Composition based on IVI at Sapling Level from 2013 to 2018



*) 2018 before earthquake and **) after the earthquake

Figure 9. Changes in Vegetation Composition based on IVI at Seedling Level from 2013 to 2018

In this study area, the highest IVIs in 2018 were before the earthquake with *Coffea robusta* (seedling; 147.84%), *C. robusta* (a sapling, 223.15%), *Theobroma cacao* (pole, 134.68%), and *Paraserianthes falcataria* (tree, 101.16%). 2018 after earthquake data did not show a significant difference with the data before the earthquake. After the earthquake, *C. robusta* had the highest IVI at the seedling (147.84%) and sapling (223.15%) levels. At the pole level, *T. cacao* had the highest IVI (134.68%). *P. falcataria* had the highest IVI (96.78%) at the tree level. As the local forest user groups managed some of the KHDTK areas, these IVIs, therefore, reflected the choice of significant species selection the local forest user groups. Their primary consideration was the economic value of the species or commodities being planted. Coffee and cacao have been gaining popularity over the last few years as seen by the high IVI at the seedling and sapling levels in 2018 (both before and after the

earthquake), and *P. falcataria* becomes the most planted species now at the tree level and *Theobroma cacao* at the pole level.

Figures 6 to 9 show that in 2013, *Erythrina variegata* had the highest IVI for tree and pole levels (86.18% and 78.65%, respectively), and *C. robusta* had the highest IVI for the sapling and seedling levels (152.99% and 115.56%, respectively). This indicated changes in farmers' preference from *E. variegata* (Highest IVI in 2013) to *P. falcataria* (highest IVI in 2018).

We noted that *Calliandra haematocephala* was found at the pole level in 2013 (Figure 7) but was absent at all regeneration levels in 2018 before the earthquake and after the earthquake. The farmers illegally cut down the species between 2013-2018 for building materials. Gunawan, Basuni, Indrawan, Prasetyo, & Soedjito (2011) stated that these plant species' adaptability strongly influences the seedling growth rate.

Avolio et al. (2019) described that disturbance could eradicate the dominant species. Muhdi, Elias, Murdiyarso, & Matangaran (2012) highlighted that timber harvest could inflict high disturbance to soil and forest stand, influencing forest regeneration at the next phase of the regeneration level. Papilaya (2016) stated that IVI shows that one species' dominance in a plant community becomes the forest community's physiognomy characteristics. The difference in the dominant species relates to environmental factors that determine which species can thrive in a habitat (García-Romero, Alanís-anaya, & Muñoz-Jiménez, 2015). Soerianegara & Indrawan (2005) stated that one of the factors influencing the number of planted species, influenced by the IVI value, was more due to changes in the species growth site due to disturbance to the ecosystem. Even in a stable ecosystem, changes will occur at the growing site gradually. In this

study, the authors posit the species' changes and its IVI value are influenced by illegal logging practices and the agroforestry practices where the farmers plant only a limited species set. Dominant tree and pole levels changed from *E. variegata* in 2013 to *P. falcataria* in 2018 (before and after the earthquake). Table 1 presents changes in Species Diversity Index (H'), Species Richness (R'), and Species Evenness (E').

Table 1 shows a significant decrease in species diversity, species richness, and species evenness during five years from 2013 to 2018 (before the earthquake) in all regeneration stages except for a slight increase in R' at the sapling level. When comparing the 2018 data before and after the earthquake, our analysis shows that the species diversity, species richness, and species evenness for the sapling and pole levels were the same. At the same time, a slight decrease was observed for seedling and tree levels.

Table 1. Species diversity index (H'), species richness index (R'), and species evenness index (E') at various regeneration stage at various years of measurement

No.	Regeneration Level	H'	R'	E'
1	Seedling Level			
	2013	0.87	0.84	0.38
	2018*	0.56	0.74	0.27
	2018**	0.53	0.75	0.26
2	Sapling Level			
	2013	1.12	0.98	0.54
	2018*	0.75	0.99	0.36
	2018**	0.75	0.99	0.36
3	Pole Level			
	2013	2.36	2.85	0.83
	2018*	1.76	2.10	0.71
	2018**	1.76	2.10	0.71
4	Tree Level			
	2013	2.05	3.52	0.79
	2018*	1.87	2.99	0.71
	2018**	1.83	2.93	0.69

Remarks: *: measurement of before earthquake; **: measurement of after earthquake; H': Weinner Species Diversity Index; R': Margalef Species Richness Index; E': Pielou Species Evenness Index

The Diversity Index (H') for the seedling level at all years of measurement is below 1.0 and categorized as low ($H' < 1$) (Nirwana et al., 2017). The Diversity Index for seedling decreased from 0.87 in 2013 to 0.56 in 2018 before the earthquake. A further slight decrease was observed in 2018 after the earthquake, where the H' for seedling was 0.53. The Diversity Index for the sapling level changed from moderate (1.12 in 2013) to low (0.75 in 2018 before the earthquake). The disturbance is suspected of causing a decrease in the number of species found, which affected the Diversity Index value changes. Xue, Yang, Miao, Wang, & Shen (2018) added that species diversity changes are influenced by the number of species found and the magnitude of land degradation and slope. This study revealed no changes in the Diversity Index at the sapling level before and after the earthquake (0.75). The species diversity at the pole and tree levels were categorized as moderate ($1 < H' < 3$ (Nirwana et al., 2017)) with the values at 2.38, 1.76, 1.76 for pole and 2.05, 1.87, 1.83 for trees, 2013, 2018, before and after the earthquake respectively. The pole and tree community had undergone stable growth evolution affecting the species heterogeneity and environment complexity and stability, which allowed only some species to excel in the competition to dominate the community. Antão, Pöyry, Leinonen, & Roslin (2020), and Ponge (2014) explained that the more mature community would quickly adapt to the slightest disturbance than the other communities. Utomo, Basyuni, Batubara, & Utara (2012) added that species diversity is a community characteristic based on the organization used to determine its structure.

In this study, species richness (S) counts the number of unique species in the studied plots (Pepper, Gerba, & Gentry, 2014). Table 1 shows that, in general, the species richness in the study site was low

(0.74 – 3.52) at all regeneration stages across the three-time scales. The only moderate value (3.52) was at the tree level in 2013. All the indices were categorized as low (except for tree-level in 2013). The changes in Species Richness Indices occurred from 2013 to 2018 before the earthquake in all regeneration stages (tree from 3.52 to 2.99; pole from 2.85 to 2.10; sapling from 0.98 to 0.99; and seedling from 0.84 to 0.75). These indices did not show significant differences for 2018 before the earthquake and 2018 after the earthquake. A slight decrease was recorded for tree-level (from 2.99 before the earthquake to 2.93 after the earthquake). The data show that more notable species richness changes occurred from 2013 to 2018 (as opposed to 2018 before the earthquake and after the earthquake where only slight changes were observed). As the local user groups use KHDTK Senaru for agroforestry practices, the anthropogenic activities impacted the species richness compared to the after earthquake period. The Species Richness Index in KHDTK Senaru was low because people preferred to cultivate high economic potential species. We recommend that the forest manager or user to consider managing diversity in KHDTK Senaru forest as long-term studies have shown that vegetation is more productive in the long run when more plant species are present (Reich, Tilman, Isbell, Mueller, Hobbie, Flynn, & Eisenhauer, 2012). Furthermore, their study also showed how diversity works by demonstrating that different species have different ways of acquiring water, nutrients, and carbon--and maintaining them in the ecosystem.

Mawazin & Subiakto (2013) stated that in addition to the Species Diversity Index (H') and Species Richness Index (R'), the Evenness Index (E') also plays an essential role in community stability. Table 1 showed that the low category could be found at the seedling level in

2018 before the earthquake (0.27) and 2018 after the earthquake (0.26). For 2013, the seedling level fell under the moderate category (0.38). Sapling level fell under the moderate category in 2013, 2018, before and after the earthquake. Meanwhile, pole and tree levels were classified as high. High E' number indicated that the species sustainability at the pole and tree levels tended to be well preserved and did not have eco-physiological disturbance, and even more stable and adaptive towards the disturbance. Kuswanto, LUGRAYASA, & SUJARWO (2018) explained that the values of H', R' and E' indicate that the conditions are moderate to low, indicating that the community is in undergoing a process of succession and approaching a stable condition. Whereas if H', R' and E' are high, then the community is susceptible to interference.

C. Changes of Carbon Storage in KHDTK Senaru Before and After Earthquake

Figure 10 shows that carbon stock changes are carbon stored above-ground as biomass, litter, or soil. Carbon stock in an area is dynamic, meaning that it can change (increasing or decreasing) within a relatively short period due to the loss or the growth phase changes within the trees species. The average above-ground carbon in KHDTK Senaru in 2018 before the earthquake was 89.09 tons/ha, and the average soil carbon was 62.18 tons/ha. Thus, the total amount of carbon stock in KHDTK Senaru in 2018 before the earthquake was 151.27 tons/ha. Nero & Callo-concha (2018) stated that the high value of carbon stock is influenced by species density in the forest community. Purwanto et al. (2012) stated that the carbon stock in KHDTK Senaru, can be categorized as high because it stores >100 tons/ha carbon. Rahayu, Lusiana, & Noordwijk (2004) added that the carbon stock in the tropical forest in Indonesia is around 61-300 tons/ha. In Asia, potential

carbon storage is around 40-250 tons/ha for vegetation (Lasco, 2002). Based on those studies, we can conclude that the carbon stock in KHDTK Senaru is still categorized as high.

Each stage (tree, pole, sapling, and seedling) in every species has a different carbon value. During the three studied years, the highest carbon stock was found at the tree level (70.53 tons C/ha in 2013, 79.83 tons C/ha in 2018 before the earthquake, and 73.87 tons C/ha in 2018 after the earthquake). At the sapling level (3.8 tons C/ha), carbon stock was higher than the pole level (2.2 tons C/ha) due to the lower vegetation at the pole level in 2018 before and after the earthquake. This result contradicted previous research, which stated that the carbon stock at the sapling level would be lower than at the pole level because of lower carbon absorption by vegetation at the sapling level due to its location under big trees (Waqar et al., 2020). We concluded that carbon stock in an area could also be influenced by the number of vegetation found in that area.

The total above-ground carbon stored in KHDTK Senaru was higher than in Mekar Sari partnership areas in Rinjani Barat Protection Forest Management Unit (24.86 tons C/ha), but lower than in the secondary dryland in *Shorea spp.* forest in Sungai Peniti West Kalimantan (99.61%) (Saputra, Hadiyansyah, & Fahrizal, 2018) and in Customary Forest (466.41 tons C/ha) (Kasianus, Astiani, & Iskandar, 2018).

Figure 10 shows changes in both the above-ground and the soil carbon stocks in KHDTK Senaru from 2013 to 2018, where the average increase was around 19.06%. It indicated that in five years, there had been a change in carbon stock in KHDTK Senaru. Based on these research findings, some sample plots show an increasing value, while some show a decreasing value. These changes were due to vegetation species and density, soil type, and management type in each plot.

Table 2. Changes in the average reserve C above ground level in the KHDTK Senaru

Average C-Storage (Years)	Carbon Storage for each stage (ton/ha)			Above Ground C-Total
	Tree	Pole	Sapling	
2013	70.53	9.45	3.48	84.35
2018 before earthquake	79.83	2.22	3.83	89.09
2018 after earthquake	73.87	2.22	3.82	79.91

An increase in carbon stock has a positive correlation with biomass, which is influenced by the tree's number and size. However, after the earthquake, the average carbon stock decreased by 6.49% compared to before the earthquake. Suwardi, Mukhtar, & Syamsuardi (2013) stated that losing biodiversity due to disturbance in any type of land use will decrease carbon storage. Besides, the disappearance of dominant species in a community will also decrease carbon storage.

IV. CONCLUSION

This study discussed vegetation cover changes, diversity, and carbon storage in KHDTK Senaru during a three-time scale (2013, 2018, before the earthquake, and 2018 after the earthquake). The dense category of vegetation cover decreased by 3.57% from 2013 to 2018 before the earthquake and decreased further to 1.74% after the earthquake. The moderate category fluctuated from an increase of 2.38% between 2013 and 2018 before the earthquake to a decrease of 2.06% after the earthquake. Meanwhile, the sparse area increased by 3.79% from 2018 before and after the earthquake. The vegetation diversity in KHDTK Senaru, regardless of the year studied (2013 and 2018), was low as indicated by the H' and d-margalef values, which fall under the low category. The carbon storage fluctuated in each time scale (84.35 tons/ha in 2013; 89.09 tons/ha in 2018 before the earthquake; 79.91 tons/ha). The 6.49% decrease in carbon stock from 2018 before the earthquake to 2018 after the earthquake primarily occurred at the tree level. This research

implies that, by assessing the changes in vegetation covers, diversity, and carbon storage, the managers can detect what kind and the size of the damage, the location, and the causes of damage. Therefore, managers can develop well-informed policies and scenarios after an earthquake to prevent the expansion of changes either caused by earthquakes directly or by anthropogenic activities.

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REFERENCES

- Agus, F., Hairiah, K., Mulyani, A., & Centre, W. A. (2011). *Measuring carbon stock in Peat Soil: Practical Guidelines*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program, Indonesian Centre for Agricultural Land Resources Research and Development. 60p.
- Andari, S. Y., Herlina, N., & Yamika, W. S. D. (2018). The effect of parks to CO₂ concentration and ambient air temperature in Malang. *Jurnal Produksi Tanaman*, 6(4), 602–608.
- Antão, L. H., Pöyry, J., Leinonen, R., & Roslin, T. (2020). Contrasting latitudinal patterns in diversity and stability in a high-latitude species-

- rich moth community. *Global Ecology and Biogeography*, 29(5), 896–907. doi.org/10.1111/geb.13073.
- Arifanti, V. B., Dharmawan, I. W. S., & Wicaksono, D. (2014). Carbon stock potency of sub montane forest stand in Mount Halimun Salak National Park. *Jurnal Penelitian Sosial Ekonomi Kehutanan*, 11(2005), 13–31.
- Ashazy, A. A., & Cahyono, A. B. (2013). Analisis indeks vegetasi menggunakan citra satelit Formosat-2 di daerah perkotaan (Studi kasus: Surabaya Timur). *Jurusan Teknik Geomatika*, 9(1), 88. https://doi.org/10.12962/j24423998.v9i1.749
- Avolio, M. L., Forrestel, E. J., Chang, C. C., La Pierre, K. J., Burghardt, K. T., & Smith, M. D. (2019). Demystifying dominant species. *New Phytologist*, 223(3), 1106–1126. doi.org/10.1111/nph.15789.
- Badan Standardisasi Nasional (BSN). (2014). *Metode penilaian jasa lingkungan keanekaragaman hayati (biodiversity)*. Badan Standardisasi Nasional.
- García-Romero, A., Alanís-anaya, R. M., & Muñoz-Jiménez, J. (2015). Environmental factors that affect primary plant succession trajectories on lahars (Popocatepetl Volcano, Mexico). *Journal of Mountain Science*, 12(5), 1254–1266. doi.org/10.1007/s11629-014-3237-4.
- Gunawan, W., Basuni, S., Indrawan, A., Prasetyo, L. B., & Soedjito, H. (2011). Analysis of composition and structure of vegetation on restoration efforts of the Gunung Gede Pangrango National Park forest area. *Journal of Natural Resources and Environmental Management*, 1(2), 93. doi.org/10.29244/jpsl.1.2.93.
- Hairiah, K. (2018). Soil carbon transitions supporting climate change mitigation. *Journal of Soil Science and Agroclimatology*, 15(2), 134. https://doi.org/10.20961/stjssa.v15i2.24972
- Idris, M. H., Latifah, S., Aji, I. M. L., Wahyuningsih, I. E., & Ningsih, R. V. (2013). Studi vegetasi dan cadangan karbon di Kawasan Hutan Dengan Tujuan Khusus (KHDTK) Senaru, Bayan Lombok Utara. *Jurnal Ilmu Kehutanan*, 7(1), 25–36.
- Indriyanto. (2008). *Ekologi Hutan*. Jakarta: Bumi Aksara.
- Januhariadi, Idris, M. H., & Silamon, R. F. (2005). Analysis of land suitability for forest trees species in forest for special purpose (education forest) Senaru, North Lombok, using geographic information system. *Universitas Mataram*, 42(4), 1. doi.org/10.1017/CBO9781107415324.004.
- Kasianus, R., Astiani, D., & Iskandar. (2018). Carbon stock estimation of above ground forest on various canopy covers in Pengajit customary forest of Bengkayang Regency. *Jurnal Hutan Lestari*, 6, 952–962.
- Koresawa, A. (2009). The Yogyakarta and Central Java earthquake 2006. *Recovery Status Report*. doi.org/10.1093/infdis/jis036
- Kusmana, C. (2017). *Metode Survey dan Interpretasi Data Vegetasi*. Bogor: IPB Press.
- Kuswantoro, F., Luguayasa, I. N., & Sujarwo, W. (2018). Quantitative ecological study of pilan forest as a baseline for development of Gianyar Botanic Garden. *Journal of Forest Science*, 12(2), 184. https://doi.org/10.22146/jik.40147
- Lasco, R. D. (2002). Forest carbon budgets in Southeast Asia following harvesting and land cover change. *Science in China*, 45, 55–64.
- Mawazin & Subiakto, A. (2013). Species diversity and composition of logged over peat swamp forest in Riau. *Forest Rehabilitation*, 1, 59–73.

- Mueller-Dombois, D., & Elenberg, H. (1975). The Count-Plot Method and Plotless Sampling Techniques. In *Aims & Methods of Vegetation Ecology*, 2(2), 158–159. doi.org/10.1016/0304-3746(75)90017-7.
- Muhdi, Elias, Murdiyarso, D., & Matangaran, J. R. (2012). Residual stand damage caused by conventional and reduced impact logging in the tropical natural forest (A case study in forest concession areas of PT. Inhutani II, East Kalimantan). *Jurnal Manusia Dan Lingkungan*, 19(3), 303–311. doi.org/10.22146/jml.18468
- Nero, B. F., & Callo-concha, D. (2018). Structure, diversity, and carbon stocks of the tree community of Kumasi, Ghana. *Forest*, 1–17. doi.org/10.3390/f9090519
- Nirwana, Hiola, S. F., & Karim, H. (2017). Analysis of epiphytic orchid vegetation in Tompobulu Resort, Balocci Village, Bantimurung Bulusaraung National Park, Pangkep Regency. *Prosiding Seminar Biologi dan Pembelajarannya*. (hal.347–352).
- Pamoengkas, P., & Zamzam, A. K. (2017). Composition of functional species group at silviculture system of Tebang Pilih Tanam Jalur in IUPHHK-HA Area of PT. Sarpatim, Central of Kalimantan. *Jurnal Silviculture Tropika*, 8(3), 160–169.
- Papilaya, P. M. (2016). Vegetation physiognomy, diversity, evenness and abundance of trees in the Protected Sirimau Forest Soya Village, Ambon City. *Journal of Natural Sciences Research*, 6(8), 28–41.
- Pebrianto, F., Akhmad, A., & Hidayat, N. (2018). This is complete data on BNPB version of Lombok earthquake damage. *Tempo.Co*. Retrieved from <https://bisnis.tempo.co/read/1125319/ini-data-lengkap-kerusakan-gempa-lombok-versi-bnpb>. on 10 September 2018.
- Pepper, I. L., Gerba, C. P., & Gentry, T. J. (2014). *Bioinformation and 'Omic Approaches for Characterization of Environmental Microorganisms* (third). Elsevier Inc.
- Ponge, J. F. (2014). Disturbances, organisms and ecosystems: A global change perspective. *Ecology and Evolution*, 3(4), 1113–1124. doi.org/10.1002/ece3.505
- Pugnaire, F. I., Morillo, J. A., Peñuelas, J., Reich, P. B., Bardgett, R. D., Gaxiola, A., ... Van Der Putten, W. H. (2019). Climate change effects on plant-soil feedbacks and consequences for biodiversity and functioning of terrestrial ecosystems. *Science Advances*, 1–12.
- Purwanto, R. H., Rohman, Maryudi, A., Yuwono, T., Permadi, D. B., & Sanjaya, M. (2012). Potensi biomassa dan simpanan karbon jenis-jenis tanaman berkayu di hutan rakyat Desa Nglanggeran, Gunung Kidul, Daerah Istimewa Yogyakarta. *Jurnal Ilmu Kehutanan*, 4(2), 128–141.
- Quesada, C. A., Paz, C., Mendoza, E. O., Phillips, O., Saiz, G., & Lloyd, J. (2020). Variations in soil chemical and physical properties explain basin-wide variations in Amazon forest soil carbon densities. *Soil*, 6, 53–88. doi.org/10.5194/soil-6-53-2020.
- Rahayu, S., Lusiana, B., & Van Noordwijk, M. (2004). Aboveground carbon stock assesment for various land use systems in Nunukan, East Kalimantan. Dalam B. Lusiana, M.V. Noordwijk, & S. Rahayu (Eds.) *Carbon Stocks Monitoring in Nunukan, East Kalimantan: A Spatial and Modelling Approach*. Bogor: World Agroforestry Centre.
- Reich, P. B., Tilman, D., Isbell, F., Mueller, K., Hobbie, S. E., Flynn, D. F. B., & Eisenhauer, N. (2012). Impacts of biodiversity loss escalate

- through time as redundancy fades. *Science*, 336 - 589. doi.org/10.1126/science.1217909.
- Rozak, A. H., Sri, A., Zaenal, M., Endah, S., & Didik, W. (2020). Efektifitas penggunaan tiga keanekaragaman pohon dalam analisis komunitas hutan: Studi kasus di Taman Nasional Gunung Gede Pangrango. *Jurnal Penelitian Hutan dan Konservasi Alam*, 17(1), 35-47. doi.org/10.20886/jphka.2020.17.1.35-47.
- Saputra, H., Hardiansyah, G., & Fahrizal. (2018). Estimation of carbon stock at merati forest management unit in Peniti Besar River, West Kalimantan Province). *Jurnal Hutan Lestari*, 6, 261–267.
- Simon, H. (2007). *Statistik untuk kehutanan*. Yogyakarta: Pustaka Pelajar.
- Siringoringo, H. H. (2014). Decrease in soil organic carbon stock on young shorea leprosula Miq. Plantation in Ngasuh, Bogor District. *Jurnal Penelitian Hutan Tanaman*, 11(2), 105–121.
- Soerianegara, I., & Indrawan, A. (2005). *Ekologi hutan Indonesia*. Bogor: Laboratorium Ekologi Hutan, Departemen Manajemen Hutan, Fakultas Kehutanan IPB.
- Song, Z., Seitz, S., Li, J., Goebes, P., Schimdt, K., Kühn, P., ... Scholten, T. (2019). Tree diversity reduced soil erosion by affecting tree canopy and biological soil crust development in a subtropical forest experiment. *Forest Ecology and Management*, 444, 69-77. doi: https://doi.org/10.1016/j.foreco.2019.04.015
- Standar Nasional Indonesia (SNI) 7724. (2011). *Ground based forest carbon accounting in Indonesia (SNI 7724-2011)*. Badan Standardisasi Nasional.
- Suwardi, A. B., Mukhtar, E., & Syamsuardi. (2013). Species composition and carbon stock in Tropical Lowland Forest, Ulu Gadut, West Sumatra. *Berita Biologi*, 12(2), 169–176.
- Samsuudin, I., Heriyanto, N. M., & Endro, S. (2010). Struktur dan komposisi jenis tumbuhan hutan pamah di Kawasan Hutan dengan Tujuan Khusus (KHDTK) Carita, Provinsi Banten. *Jurnal Penelitian Hutan dan Konservasi Alam*, 7(2), 139-148. doi.org/10.28886/jphka.2010.7.2.
- Tahura, T., Abdul, W. A. N., Wahyudi, A., Harianto, S. P., Darmawan, A., & Rachman, A. (2014). Trees diversity in the Tahura Wan Abdul Rachman Educational Forest. *Jurnal Sylva Lestari*, 2(3), 1–10.
- Tampubolon, T., & Yanti, J. (2015). Application of landsat satellite image utilization in medan city and its surrounds. *Jurnal Fisika Dan Aplikasinya*, 16(2), 15–19.
- Utomo, B., Basyuni, M., Batubara, M., & Utara, U. S. (2012). The potential of stands in the former traditional mining preserve Forest Mandailing Natal. *Journal of Forestry*, 1(2), 58–69.
- Waqar, M. M., Sukmawati, R., Ji, Y., Sumantyo, J. T. S., Segah, H., & Prasetyo, L. B. (2020). Retrieval of tropical peatland forest biomass from polarimetric features in Central Kalimantan, Indonesia. *Progress In Electromagnetics Research*, 98, 109–125. doi.org/10.2528/PIERC19082804.
- Xue, R., Yang, Q., Miao, F., Wang, X., & Shen, Y. (2018). Slope aspect influences plant biomass, soil properties and microbial composition in alpine meadow on the Qinghai-Tibetan Plateau. *Journal of Soil Science and Plant Nutrition*, 18(1), 1-12.