PLANT SPECIES DIVERSITY AND ESTIMATION OF ABOVEGROUND CARBON STOCK IN WAY CANGUK RESEARCH STATION, BUKIT BARISAN SELATAN NATIONAL PARK

UNDERGRADUATE THESIS

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UNDERGRADUATE THESIS PRESENTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE

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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

Alhamdulillah… Alhamdulillahirabbil 'alamin

Terima kasih kepada Allah SWT, Tuhan segala alam semesta atas karunia dan rahmat-Mu, hambamu mampu menyelesaikan perjalanan dalam menempuh pendidikan ini.

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-Imam Syafi'I-

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PREFACE

First and foremost, the author devotes her gratitude to Allah SWT for mercy and grace in enabling that accompanying accomplishment of this thesis. This thesis is based on the study in the field of Plant Ecology entitled **"Plant Species Diversity and Estimation of Aboveground Carbon Stock in Way Canguk Research Station, Bukit Barisan Selatan National Park"**. The completion of research and thesis writing would serve as the fulfilment of requirements to achieve the bachelor degree in Biology at Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Andalas Padang.

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Author

ABSTRACT

Most of Sumatran landscapes are dominated by lowland tropical forests with high biodiversity and posseses the potential to store carbon stock that play an important role in maintaining the stability of global climate. The stability and resilience of a forest ecosystem can be determined by looking into plant species diversity and carbon stock it retains. This research aims to determine plant species diversity on tree and sapling level, as well as to estimate aboveground carbon stock stored at Way Canguk Research Station, Bukit Barisan Selatan National Park, Lampung. This research used non-destructive sampling method for tree and sapling, while the destructive sampling method was deployed for understorey and litter covers. The Way Canguk Research Station area has high diversity tree (H’ = 3.30) and sapling (H’ = 3.28) which may caused by various plant species inhabit the area. Meanwhile, the carbon stock was calculated to be 351.638 ton/ha on tree criteria, 5.28 ton/ha for sapling criteria, 0.09 ton/ha for understorey coverage and 1.82 ton/ha for litter. The total carbon stock was 358.828 ton/ha, placed Way Canguk Research Station as high carbon stock area and categorized as High-Density Forest (HK 3).

Keyword: *biomass, carbon stock, destructive, diversity index, forest*

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I. INTRODUCTION

1.1 Background

The tropical forest is a unique ecosystem that lies around the equator with considerable temperature, humidity, and average annual rainfall (Alikodra, 2020). Tropical rainforest ecosystems can control soil erosion and flooding, absorb various pollutants, stabilize the microclimate, and play an important role in regulating global climate. In many developing countries, however, forest is perceived to be a source of readily income and exploiting through deforestation and land clearing (Alikodra, 2020).

Lowland tropical forests that dominates Sumatran landscapes posseses high biodiversity (Suwardi *et al.*, 2013). In addition to its biodiversity, Indonesian tropical forest stores huge amount of carbon stock and play an important role in maintaining the stability of global climate. Chemically, vegetation community in forest absorb carbon through photosynthesis and store it within vegetation biomass, litter, necromass, and soil organic matter. Information regarding aboveground biomass is required to estimate ecosystem productivity, carbon stock, nutrient distribution, and fuel accumulation (Suryandari *et al.*, 2019).

The largest carbon stocks are stored in unspoiled forests with a diverse long-lived plant species and accumulated litter. Deforestation significantly contributes to climate change or global warming, responsible for approximately 20-25% of global carbondioxide (CO_2). At the United Nations Climate Change Conference's Conference of the Parties 13 in Bali in December 2007, the expansion of the carbon market for CO_2 mitigation was agreed upon, as was the plan of reducing emissions from deforestation and forest degradation (REDD). Carbon dioxide is absorbed through photosynthesis and stored within carbon pockets in the roots, stems, and leaves before being released back into the atmosphere as carbohydrates (Yastori *et al.*, 2007).

Research on the potential carbon stocks was previously conducted at sub-montane forest stands in Mount Halimun Salak National Park (Arifanti *et al.*, 2014). It concluded that the sub-montane forest in Mount Halimun Salak National Park is still intact, indicated bt its carbon storage at aboveground measured at 139.326 tonC/ha, below ground at 39.011 tonC/ha, understorey at 1.971 tonC/ha, and necromass at 5.77 tonC/ha. The average standing biomass and carbon stock in this primary forest are respectively 364.503 ton/ha and 185.177 ton/ha.

Another study was also conducted at the roadside of Lore Lindu National Park (Sedjarawan *et al.*, 2014). It measured the aboveground tree biomass at observation plot of 10 m away from the roadside reached 711 ton/ha and the observation plot of 100 m away from roadside measured at 256 ton/ha. The aboveground tree carbon in the observation plot 10 m away on the roadside of Lore Lindu National Park was 355.6 ton/ha and the observation at plot 100 m away from the edge of Lore Lindu National Park was 128.0 ton/ha.

Another study estimated carbon stocks at lowland tropical forest in Pinang-Pinang forest in West Sumatra by identifying plant species composition and their carbon storage capacity (Suwardi *et al.*, 2013) It identified 155 plant species of 45 families from 852 tree individuals surveyed, all with 8 cm DBH. The study site was dominated by *Nephelium juglandifolium, Swintonia schwenkii, Syzygium* sp., *Microcos florida, Palaquium* sp., *Cleistanthus glandulosus, Hopea dryobalanoides, Mastixia trichotoma, Calophyllum ssoulattri,* and *Shorea maxiwelliana.* Tree biomass was measured at 482.75 tons/ha, while carbon stock was assessed to be 241.38 tons/ha. Large trees with 100 cm or more DBH contributed 26.62% to the carbon stocks in the study site.

Bukit Barisan Selatan National Park (BBSNP), one of protected area in Sumatra and consist of tropical forest area, has importants function as habitat for wildlife as well as stabilizing the global climate by storing carbon. Way Canguk Research Station (hereinafter WCRS) is a research station collaboratively managed by the Wildlife Conservation Society-Indonesia Program (WCS-IP) and Bukit Barisan Selatan National Park Office. There is approximately 800-900 ha in WCRS designated as research area. This research area comprises only 0.22% of the total 313.572,48 ha of BBSNP area (Taman Nasional Bukit Barisan Selatan, 2015).

The level of stability and resilience of a forest ecosystem can be assessed from two perpective; species diversity (Kasim and Hamid, 2015) and carbon stock (Yastori *et al.*, 2016). Therefore, WCRS has commited to carry out a routine on the dynamics of plant community since 1997. The WCRS has made estimated on carbon stock from biomass data collected at 100 permanent plots showed declination from 1.715 Mg (megagram, 1 Mg = 106 gram) in 1997 to 1.684 Mg in 2017. Similarly, the estimated biomass density slightly went down from 343 Mg/ha in 1997 to 337 Mg/ha in 2017, hence the total carbon stock assessed respectively as 168 Mg/ha in 1997 to 165 Mg/ha in 2017 (Utoyo *et al.*, 2020). This estimation, however, is not final, as it only counted trees more than 10 cm DBH into the general allometric equation develop by Brown (1997). Hence, further studies that include more parameters into the assessment are welcome.

The use of species-specific equations is more preferable in estimating aboveground biomass due to the extent of differences of tree architectures and wood density when estimating the above-ground biomass of a forest, the use of species-speciic equations are preferred because trees of different species may differ greatly in tree architecture and woody density (Kattering *et al.*, 2001),. Therefore, this study affords to obtain more accurate assessment on biomass estimation and carbon stock by developing allometric equation developed recently for that purpose (Chave *et al.*, 2014). This equation adds parameters for wood density and tree height which previously exclude. The amount of aboveground biomass is specifically calculated from the tree, sapling, understorey, and litter. Moreover, plant species diversity is also monitored in this study to give update on floral biodiversity, in WCRS of BBSNP.

1.2 Research Questions

Accoeding to what detailed in the background section above, two problems are formulated ass bellow:

1. How diverse the trees and saplings in Way Canguk Research Station?
2. What is the total aboveground carbon stock in Way Canguk Research Station?

1.3 Research Objectives

1. To determine the species diversity of trees and saplings in Way Canguk Research Station.
2. To estimate the total aboveground carbon stock at Way Canguk Research Station.

1.4 Research Benefits

1. Updating species diversity that comprise the tree and sapling strata in Way Canguk Research Station.
2. Provide more accurated assessment on aboveground carbon stock from trees, saplings, understorey, and litter in Way Canguk Research Station.
3. Improving the knowledge of those who read this study, particularly regarding plant ecology, vegetation analysis, biomass, and carbon stock estimation, as well as serving as reference for further researches.

II. LITERATURE REVIEW

2.1 Forest

Forest is an ecosystem unit in the form of land containing biological natural resources which are dominated by trees in their natural environment and cannot be separated from one another. Plant community in forest is dominated by trees and woody plants (Law No. 41 of 1999). Forest is divided into conservation forests, protection forests, and production forests based on their function (Government Regulation of the Republic of Indonesia No. 34 of 2002)

Law no. 5 of 1990 futher defines the functions of conservation forests to preserve ecosystems and protect biodiversity in that area. Hence, conservation forests should have certain characteristics, to be able to carry their main function in preserving plant and animal diversity and their ecosystems (Napitu, 2017). A protected forest has the main functions for protecting natural life support system, such as regulating water systems, preventing flood, erosion, seawater intrusion, and maintaining soil fertility. In contrary, production forests function as source of forest poducts or purposively maintained for the benefit of industrial consumption and export (Law No. 41 of 1999).

In addition to being home for wildlife, forests also act as carbon sinks and carbon sources (Wibowo and Ginoga, 2010). Forest vegetation can absorb CO_2 through photosynthesis resulting as carbohydrate products that stored as biomass in roots, stems, branches, and twigs. The denser forest vegetation, more CO_2 will be absorbed there. In that case, the rehabilitation of degraded forests by tree planting help increasing absorption of CO_2 in the atmosphere (Salisbury and Ross, 1992).

2.2 Carbon Emission

The carbon release into the atmosphere through respiration of living things, decomposition of organic matters, and biomass burning. The microorganisms (bacteria and microbes) present within the dead plants or animals enhance decomposition process that also freeing CO_2. The excessive anthropogenic interferences into forest ecology, will accelerate the emissions out of the decomposition matters. The anthropogenic emissions exceed the rate of carbon sequestration by forest, increasing CO_2 content in atmosphere while forest area keep shrinking (Manuri *et al.*, 2011).

The global warming is considered as one among causes of climate change. Global warming due the increasing concentrations of greenhouse gases in atmosphere affect many ecosystems on earth. The forestry sector contributes 80% of global greenhouse gas emissions especially from deforestation and forest degradation (Bappenas, 2010). Deforestation rate in Indonesia only between 2015-2016 reached 630.000 ha (KLHK, 2017). Concentration of CO_2 in earth atmosphere has increased from 277 ppm in 1750 during the industrial revolution to 400.72 ppm in 2016 (Dlugokencky and Tans, 2016). Deforestation itself is responsible for 6-17% of increasing CO_2 emissions. When trees are cut down, the stored carbon will be released into the atmosphere and contribute to the global warming (Baccini *et al.*, 2012).

2.3 Estimation of Biomass and Carbon Stock

Carbon stock storage mount differently in each lands type, depend on the diversity and density of existing plants, type of soil, and other factors. Carbon stored on terrestrial environment increase significantly with the degree of soil fertility; hence soil and organic matters contained within are determinant for carbon store age therein (Hairiah and Rahayu, 2007). Biomass is total weight or volume of organisms in a certain area (IPCC, 2001). Biomass is also defined as the total amount of living matter above the surface of a tree and is expressed in tons of dry weight per unit area (Brown, 1997). Biomass estimation is very important for calculating and monitoring carbon stocks, ecosystem productivity, and environmental damage (Das and Singh, 2016). Sutaryo (2009) defined four carbon pools that are necessary for forest carbon inventory:

1. Aboveground Biomass

   All living material above the surface included stems, stumps, branches, bark, seeds, and leaves from the trees and the understorey on the forest floor.

2. Underground Biomass

   All biomass from living plant roots. The term 'root', applies only to a certain specified diameter size, as roots with smaller diameter tend to be difficult to distinguish from other soil organic matters and litter.

3. Dead Organic Matter

   Includes decayed deadwood and litter. Litter is defined as all dead organic matters that make surface layer of soil and with diameter smaller than a predetermined diameter and with varying degrees of decomposition.

Deadwood is organic matters that not included as litter, either standing or fallen to the ground, dead roots, and stumps with a diameter greater what defined for litters.

4. Soil Organic Carbon

The carbon contained within mineral and organic soils, as well as peat.

The calculation of biomass, it usually performed using four methods, which are (1) sampling with harvesting (destructive sampling); (2) sampling without harvesting (non-destructive sampling); (3) estimation through remote sensing; and (4) modelling. In each of it, the data is extrapolated to assess wider area using allometric equations (Sutaryo, 2009). Examples of allometric equations used in calculating biomass are as follow:

Table 1. Allometric Equation to Estimate Biomass

Source	Allometric Equations
Brown *et al.* (1997)	$Y = 42.69 – 12.8 \times D + 1.242 \times D^2$
Kattering *et al.* (2001)	$W = 0.11 \text{ x } \rho D^{2.62}$
Chave *et al.* (2005)	$AGB = 0.0509 \text{ x } (\rho D^2 H)$
Basuki *et al.* (2009)	$\mathrm{Ln}\ (TAG) = -1.498 + 2.234\ \mathrm{Ln}\ (D)$
Chave *et al.* (2014)	$AGB = 0.0673 \text{ x } (\rho D^2 H)^{0.976}$

Remarks: D = *Diameter at Breast Height* (cm); H = tree height (m); = density of wood (gr/cm^3)/(kg/m^3); W/Y/AGB = Aboveground biomass

Most of aboveground forest carbon comes from tree biomass. The tabulation of biomass volumes based on allometric equations is very helpful in choosing the most appropriate method in calculating aboveground biomass and carbon. Aside its simplicity, allometric equations increases the accuracy of carbon estimation and facilitates inventory process in the forest (Manuri *et al.*, 2011).

The equation in Kattering *et al.* (2001) specifically applied on Sumatran forest and neglected the climate factor. In addition, it did not include tree height in the allometric modelling. Allometric equation in Basuki *et al.* (2009) has wider range of diameter classes (up to 200 cm) without considering climatic aspect, yet seemed to be applicable for East Kalimantan area. This allometric equation also exclude tree height. Other equations from Brown *et al.* (1997) and Chave *et al.* (2005) include both tree height and climate zone into their allometric modelling. The later was then chosen as main equation for estimating carbon stocks, as it has wider range of sample data with geographic distribution and combination of forest conditions. In addition, Chave's equation takes into account wood density of plant species. Wood density of plant species is an important variable in thoroughly estimating tree biomass (Chave *et al.*, 2005).

2.4 Way Canguk Research Station

Way Canguk Research Station (WCRS) was established in March 1997, located within Bukit Barisan Selatan National Park after the collaboration between Wildlife Conservation Society-Indonesia Program and the Directorate General of Forest Protection and Nature Conservation (PHKA). The establisment of this research station aimed to provide a better understanding on the ecosystems in Sumatran lowland tropical forest through monitoring and management of wildlife and their habitats in BBSNP. It also helps to produce conservation experts with ability to solve various conservation problems (BBTNBBS and WCS-IP, 2020).

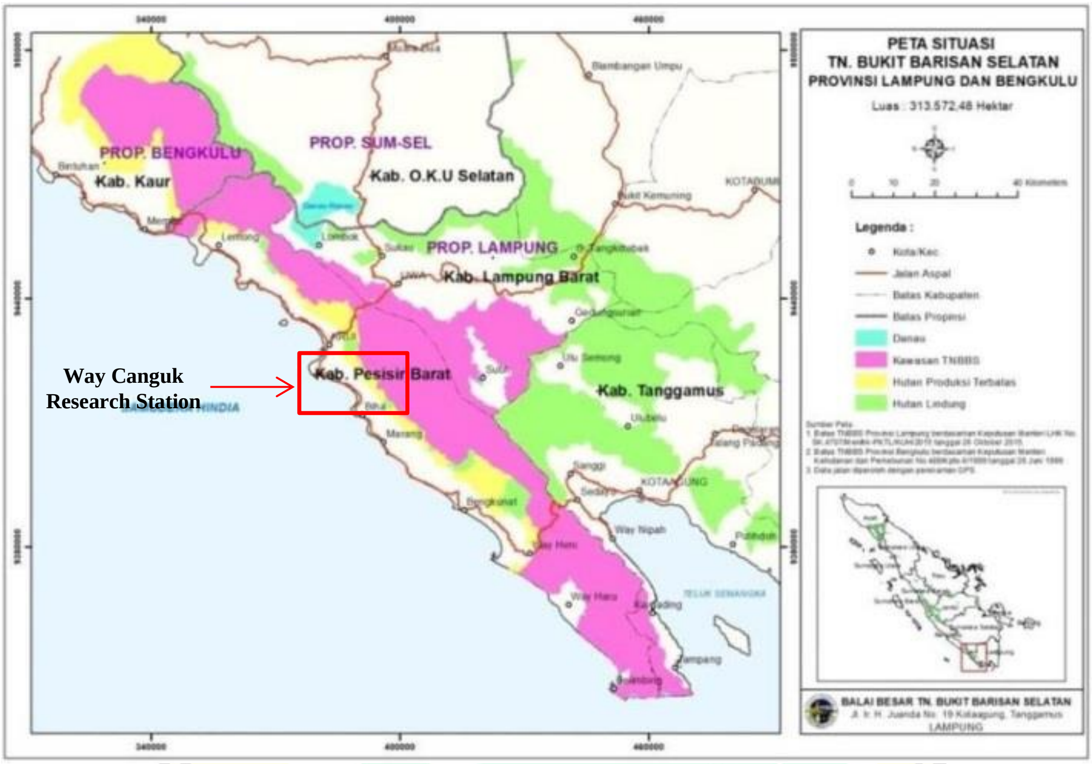

Figure. 1. Map of Way Canguk Research Station in Bukit Barisan Selatan National Park, Lampung Province (Source: BTNBBS and WCS IP, 2020)

The WCRS is located at the southern part of BBSNP, covering a 900 ha area, on which include 800 ha research area and some its 165 ha was burned in 1997 forest fire. The research area is traversed Canguk River, divided into 200 ha (northern plot) in the northwest side and 600 ha (southern plot) in the southeast side. The WCRS area is dominated by primary forest with large trees and dense crowns (BBTNBBS and WCS-IP, 2020). The WCRS harbors 56 mammal species, primates such as *Hylobates agilis*, *Symphalangus syndactylus*, *Presbytis mitrata*, and *Macaca nemestrina*, as well as 207 bird species. Some ungulates also recorded such as *Muntiacus muntjak*, *Cervus unicolor*, *Sus scrofa*, *Tragulus kanchil*, and *T. napu*. Some large mammals such as the Sumatran elephant (*Elephas maximus*), Sumatran tiger (*Panthera tigris*), tapir (*Tapirus indicus*), and Sumatran rhino (*Dicerorhinus *sumatrensis*) were also known roaming in this area despite their current existence need further investigation (Iqbal *et al.*, 2001 *cit* BBTNBBS and WCS-IP, 2020).

The WCRS has more than 420 tree species belonging to 62 families, with 296 species (Prabowo, 2018) *cit* BBTNBBS and WCS-IP (2020). Dipterocarpaceae becomes the dominant group and considered important for wildlife because as provide food and nesting site for primates and hornbills, even some hornbill nests are found in this tree. Fifty liana species and 20 orchid species complete 32 fig species found around WCRS. The figs, *Ficus* spp., are key plant species in tropical rainforest ecosystems due to their resourcefulness as food source for various types of animals.

III. RESEARCH METHOD

3.1 Time and Place

Research had been conducted from September to December 2021. Data was collected from Way Canguk Research Station include plot from northern and southern research area, Bukit Barisan Selatan National Park. Field data was then processed and analyzed at Plant Ecology Laboratory, Universitas Andalas, and at Forest Products Technology Laboratory, Universitas Lampung.

3.2 Study Area

Way Canguk Research Station is a research station collaboratively managed by the Wildlife Conservation Society-Indonesia Program (WCS-IP) and Bukit Barisan Selatan National Park Office, established in 1997 with its approximately 800 ha research area. It is located between 5°39'25"S and 104°24'21"E and between 15-70 mdpl altitude. The ecosystems are dominated primary forest, secondary forest after burned in 1997, and naturally disturbed forest (WCS-IP, 2001 *cit* Kartono *et al.*, 2009).

3.3 Materials and Equipments

The study used GPS, DBH meter, rangefinder, binoculars, digital scales, oven, sacks, 10 kg plastic, sticker label, string, plant scissor, rubber band, datasheet, camera, and stationery.

3.4 Method

The study deployed non-destructive sampling (without harvesting) for tree and sapling strata. Meanwhile, the litter and understorey used destructive sampling through harvesting (Hairiah and Rahayu, 2007).

3.5 Work Procedure

3.5.1 Plot Making

Data for this study was collected at established permanent plots in WCRS research area. One permanent plot measured 10 x 50 m which in this study divided into 5 subplots of 10 x 10 m for surveying tree strata. Nesting plots of 5 x 5 m for surveying saplings and 2 x 2 m for analysing understorey and litter were further established in each permanent plot (Badan Standarisasi Nasional, 2011). There were 20 permanent plots surveyed in this study that encompassed 0,2 ha of total area. The arrangement of study plot in this study and map of overall WCRS area are as as bellow:

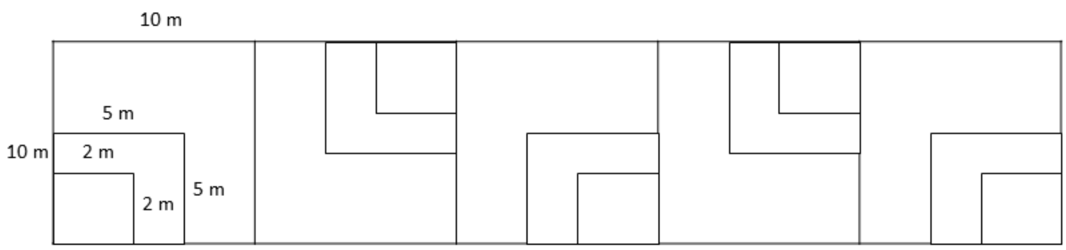

Figure. 2. Survey plot arrangement

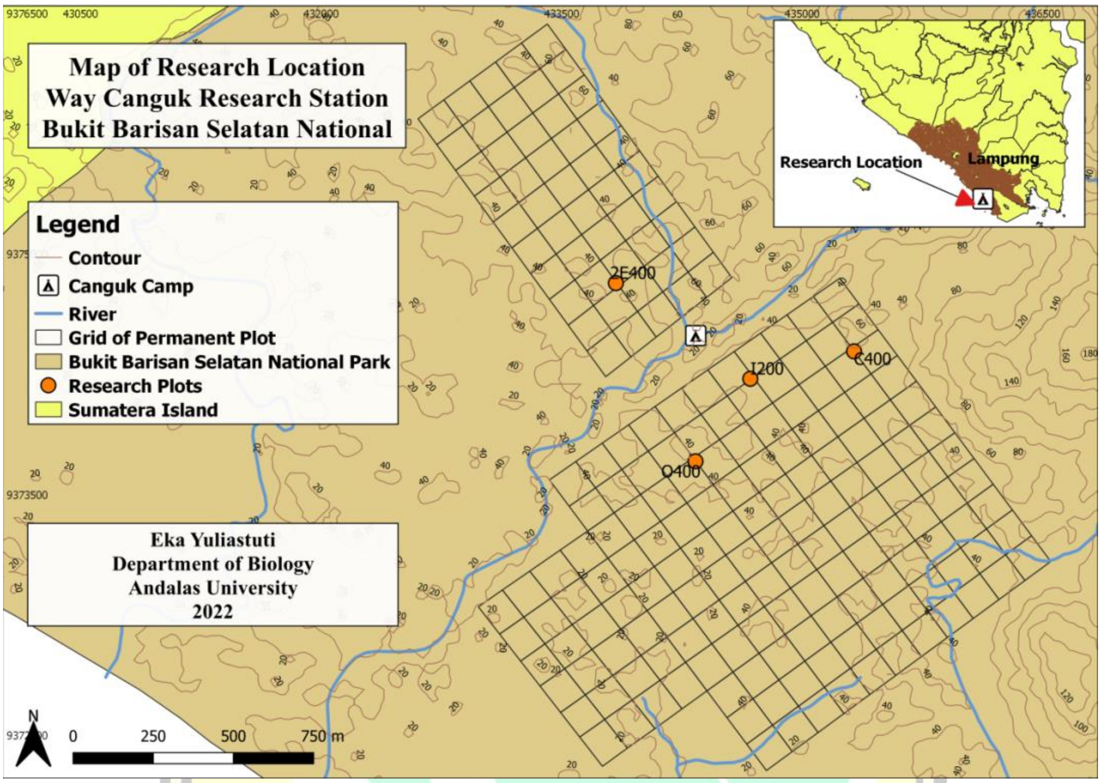

Figure. 3. Overview of WCRS research area (Source: BTNBBS and WCS IP, 2020)

3.5.2 Estimation of Biomass

The height and diameter at breast height (DBH) were measured to estimater the biomass of tree and sapling, DBH was measured at standard ±1.3 m aboveground level (BBTNBBS and WCS-IP, 2020). All understorey plants and aboveground coverage were collected from 2 x 2 m plot before weighed to get the total fresh weight in that plot. Approximately 300 g of fresh understorey sample was then dried with laboratory oven at a 85°C temperature until constant weight reached. The dry weight was weighed. Similar procedure was commended for the litters (Badan Standarisasi Nasional, 2011).

3.5.3 Measurenment of Environmental Factors

The WCRS area holds primary and secondary forest ecosystems in which the environmental factors play major role in affecting plant community dynamics. Those said environmental factors include temperature, altitude, and rainfall; all needs to be measured as secondary data to help elaborate the findings from this study.

3.6 Data Analysis

3.6.1 Species Diversity

Plant species diversity in WCRS was assessed from tree and sapling strata. Species inventory is listed in table.

3.6.1.1 Important Value Index

Important value index is obtained by adding up the relative density, relative frequency, and relative dominance; all stated in percentage (Indriyanto, 2006), with the following equation:

Table 2. The equations to count Important Value Index

Index	Equation
Relative density	$\frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$
Relative frequency	$\frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$
Relative dominace	$\frac{\text{Dominance of a species}}{\text{Total Dominace of all species}} \times 100$
Density	$\frac{\text{Number of a species}}{\text{Total area sampled}}$
Frequency	$\frac{\text{Total of plots in which a species occurs}}{\text{Total number of plots used}}$
Dominace	$\frac{\text{Basal area}}{\text{Total area sampled}}$
Importance Value Index (IVI)	Relative density + Relative frequency + Relative dominance

3.6.1.2 Diversity Index

Species diversity is calculated using Shannon-Whienner Index (H') with following formula:

$$H' = -\Sigma \text{ pi ln pi } (pi = \frac{\mathbf{ni}}{\mathbf{N}})$$

ni = Important Value Index of species

N = The total of Important Value Index

Plant diversity can be categorized as follow:

H' > 3	=	High diversity level
H' 1 ≤ H' ≤ 3	=	Moderate diversity level
H' < 1	=	Low diversity level (Fachrul, 2012).

3.6.2 Estimation of Biomass

3.6.2.1 Tree and Sapling

Biomass estimation uses allometric equation developed by Chave *et al*. (2014), as follow:

$$AGB_{est} = 0.0673 \text{ x } (\rho D^2 H)^{0.976}$$

AGB = Above Ground Biomass (kg)

ρ = density of wood (g/cm3)

The value ρ refers to list issued by ICRAF (http://db.worldagroforestry.org//wd) and the Encyclopedia of Life (https://eol.org).

D = Diameter at Breast Height (cm)

H = Tree height (cm)

3.6.2.2 Understorey and Litters

The biomass of understorey and litter was calculated using formula created by Badan Standarisasi Nasional (2011) as follow:

Total Weigh of Organic Matter (g) = $\frac{Wsubsample,\ dry}{Wsubsample,\ wet}$ x Total of Fresh Weight (g)

Wsubsample, dry = weight of the oven-dried subsample of the biomass (g)

Wsubsample, wet = weight of fresh subsample of the biomass (g)

3.6.2.3 Total of Biomass

The total of biomass was calculated using formula below:

$$\text{Total of Biomass} = AGB_{ph} + AGB_{tb} + AGB_{s}$$

AGB_{ph} = total biomass of living tree (tree and sapling) (ton/ha)

AGB_{tb} = total biomass of understorey (ton/ha)

AGB_{s} = total biomass of litter (ton/ha) (Hairiah dan Rahayu, 2007)

3.6.3 Estimation of Carbon Stock

3.6.3.1 Tree and Sapling

Estimation of tree and sapling biomass using formula from Badan Standarisasi Nasional (2011) as follow:

$$Cb = B \times \%C\ \text{organic}$$

Cb = carbon from biomass (kg)

B = total of Aboveground Biomass (AGB) (kg),

%C organic = percentage constant of carbon content which is 0.47

3.6.3.2 Understorey and Litter

The biomass at understorey and litter strata was estimated using formula from Badan Standarisasi Nasional (2011) as follow:

$$Cm = Bo \times \%C \text{ organic}$$

Cm	= carbon from organic biomass (kg)
Bo	= total of Aboveground Biomass (AGB) (kg)
%C organic	= percentage of organic carbon content (0.47)

IV. RESULT AND DISCUSSION

4.1 Species Diversity of Plant at Way Canguk Research Station

4.1.1 Tree

The vegetation survey in research area of Way Canguk Research Station, enlisted 47 plant species from 26 families, which were identified from 93 plant individuals (Appendix 5). In Table 3 below, 10 tree species with the most Important Value Index are tabulated:

Table 3. Tree species with highest Important Value Index

No	Scientific Name	Family	RDe (%)	RF (%)	RDo (%)	IVI (%)
1	*Dipterocarpus humeratus*	Dipterocarpaceae	12.9	7.69	46.52	67.11
2	*Strombosia javanica*	Olacaceae	12.9	10.26	7.01	30.17
3	*Meiogyne virgata*	Annonaceae	5.38	5.13	2.24	12.75
4	*Pseuduvaria reticulata*	Annonaceae	4.3	3.85	2.56	10.71
5	*Chisocheton ceramicus*	Meliaceae	3.23	3.85	2.97	10.04
6	*Planchonia grandis*	Lecythidaceae	1.08	1.28	7.21	9.57
7	*Dillenia excelsa*	Dilleniaceae	3.23	3.85	1.64	8.71
8	*Polyalthia cauliflora*	Annonaceae	3.23	3.85	0.9	7.98
9	*Popowia bancana*	Annonaceae	3.23	3.85	0.89	7.96
10	*Xerospermum noronhianum*	Sapindaceae	3.23	1.28	3.09	7.6

Remarks: RDe=Relative Density, RF=Relative Frequency, RDo=Relative Dominance, IVI=Important Value Index

Dipterocarpus humeratus (Dipterocarpaceae) has highest Important Value Index among other ten important tree species (IVI = 67.11%). It was subsequently followed by *Strombosia javanica* (Olacaceae) and *Meiogyne virgata* (Annonaceae) with IVI respectively 30.17% and 12.75%. Meanwhile, *Ptychopyxis costata* (Euphorbiaceae) has the lowest IVI (2.45%) (Table 3, Appendix 5). With 12 individuals found within research area, *D. humeratus* and *S. javanica* become tree species with the highest number of individuals. Both species have considerable relative density (RDe = 12.9%), with *D. humeratus* has the highest relative dominance in this study (RDo = 46.52%). The relative dominance of a species is obtained by dividing that species dominance with all species dominancy. Since the dominance of a tree related to its basal area that in turn affected by DBH, trees with bigger diameter such *D. humeratus* will have significant basal area and dominance. *D. humeratus* has diameter range from 10.4 to 138.4 cm ($\bar{x}$ = 53.2 cm) make them species with the most important value index. The important value index also implies the dominance of a species in its habitat. Species with the highest importance index are usually highly adaptive to environmental changes.

Aside being with large diameter, *D. humeratus*, also grow tall to more than 59 m with straight, and cylindrical trunk. Therefore, it's the timber, from this species is popular for building material and traded internationally. This species only recorded from Indonesia among all southeast Asia countries, where it prefers the moist, lowland area at elevation up to 600 m. Most members of *Dipterocarpus* regenerate naturally under the shade in the forest. Seedlings and saplings require uninterrupted dense forest shade provide by intact forest canopy. After reaching considerably height (usually around 120 cm), the saplings need more direct sunlight to speed up their growth (Tropical Plants Database, 2021).

Strombosia javanica is spesies that spread in the area of Burma (Myanmar), Peninsula Malay (Malaysia), and Sumatra, including Nias, Java, and Kalimantan (Rachman and Sunaryo, 1999) has highest value of relative frequency (RF = 10.26%) in this study. This tree usually growing 10-25 m tall with a dense crown, bole usually up to 70 cm in diameter, and harvested from the wild for its edible leaves and timber. This plant can found at Southeast Asia area such as Myanmar, Thailand, Malaysia, and Indonesia with habitat like lowland rain-forest, also secondary forest, and mixed Dipterocarp forest (Tropical Plants Database, 2021).

Species with lowest Important Value Index is *Ptychopyxis costata* (Euphorbiaceae) (IVI = 2.45%) (Appendix 6). *Ptychopyxis* contains 11 species, which range from Thailand throughout Malesia to New Guinea. The species is usually large, dioecious trees, with simple, ferrugineous hairs. They occurs in a wide range of habitats, varying from primary mixed dipterocarp forest to secondary forests and they are found on a wide variety of soil types in the lowlands. The species of *Ptychopyxis* show much interspecific and intraspecific variation, which often makes identification difficult. Identification is especially difficult when the specimens are sterile, though the use of combinations of vegetative characters may still facilitate identification to a certain extent. The fruits provide the most useful characters for recognition and usually fruiting in September. They are generally subglobose, densely hairy and variously ridged capsules, which tardily split when ripe. Distribution of this species located at Sumatra and Borneo while the habitat in the Dipterocarp lowland forest with altitude 50 mdpl (Stoops and Welzen, 2013).

In general, Importance Value Index (IVI) is measure of how dominant a species is in a given forest area. IVI of tree species was determined as the sum of relative frequency, relative density, and relative dominance (Curtis and McIntosh, 1950). The important value index of a species in a community is one of the parameters that shows the role of the plant species in the community. The presence of a plant species in an area shows the ability to adapt to the habitat and wide tolerance to environmental conditions. The bigger the index value of the importance of a species, greater the level of control over the community and vice versa. What is meant by species control is if the species in question succeeds in obtaining most of the available resources compared to other species (Nashrulloh, 2019).

4.1.2 Sapling

The vegetation survey in research area of Way Canguk Research Station, enlisted 43 plant species from 21 families, which were identified from 145 plant individuals (Appendix 6). In Table 4 below, 10 sapling species with the most Important Value Index are tabulated:

Table 4. Sapling Species with highest Important Value Index

No	Scientific Name	Family	RDe (%)	RF (%)	RDo (%)	IVI (%)
1	*Anaxagorea lanceolata*	Annonaceae	30.56	6.33	23.86	60.75
2	*Mallotus miquellianus*	Euphorbiaceae	9.03	10.13	4.57	23.72
3	*Dillenia excelsa*	Dilleniaceae	6.94	2.53	10.35	19.83
4	*Popowia bancana*	Annonaceae	5.56	6.33	5.19	17.07
5	*Strombosia javanica*	Olacaceae	2.78	2.53	7.02	12.33
6	*Meiogyne virgata*	Annonaceae	2.08	3.80	4.51	10.39
7	*Drypetes laevis*	Putranjivaceae	2.78	3.80	3.19	9.76
8	*Enicosanthum grandiflorum*	Annonaceae	1.39	2.53	4.42	8.34
9	*Dipterocarpus humeratus*	Dipterocarpaceae	2.08	2.53	3.53	8.14
10	*Walsura robusta*	Meliaceae	1.39	2.53	3.34	7.26

Remarks: RDe=Relative Density, RF=Relative Frequency, RDo=Relative Dominance, IVI=Important Value Index

Based on the Table 4, it can be seen that *Anaxagorea lanceolata* from the Annonaceae family is a species with highest Important Value Index (IVI = 60.75%). This species has highest value of relative density (Rde = 30.56%) and relative dominance (RDo = 23.86%), also has highest number of individuals which are 44 individuals. The large number of this species is due to the adaptability of this species. *A. lanceolata* is able to live under a dense canopy which is surrounded by trees from the Dipterocarpaceae family where only little light can reach the ground surface. In addition, the seeds of this plant are so numerous that it facilitates the propagation of this species in an area. According to Endress and Armstrong (2011), *Anaxagorea* is a genus of special phylogenetic interest in the large (112 genera, 2440 species; tropical Annonaceae because it is sister to the remainder of the family, a position first found in structural cladistic analyses and later supported by molecular analyses.

Furthermore, the second species with the highest Important Value Index value was *Mallotus miquellianus* (Euphorbiaceae) (IVI = 23.72%). Of the 144 individuals at the sapling level, *M. miquellianus* was the species with the second largest number of individuals, namely 13 individuals, but most often found in the observation plots, namely 8 of the 20 sampling plots. *Mallotus miquellianus* also pecies with the highest value of relative frequency (RF = 10.13%). This species is quite dominant and widely distributed in this area, as evidenced by the discovery of this species in 8 plots of 20 observation plots. The large number of these species is due to the fact that the genus Mallotus is one of the pioneer plant species. As a result of the succession that occurred due to the 1997 fire at the Way Canguk Research Station, the number of this species was high, especially in the area where the fire was.

Trees from the Euphorbiaceae tribe such as; Macaranga, Mallotus and Omalanthus are pioneer species that commonly fill successional forest elements.

According to Mansur (2011) on Laju Fotosintesis Jenis-Jenis Pohon Pionir Hutan Sekunder di Taman Nasional Gunung Halimun-Salak Jawa Barat, where based on the results of the survey recorded there are 6 types of pioneer trees that commonly grow around the secondary forest of Cangkuang, among them are; *Macaranga triloba* (Red Mara), *Macaranga tanarius* (Manggong), *Mallotus paniculatus* (Calik angin), *Omalanthus populneus* (Kareumbi), *Trema orientalis* (Kurai), and *Weinmannia blumei* (Peuris).

Species with the lowest Important Value Index was *Miliusa horsfieldii* (Annonaceae) (IVI = 2.13%). *M. horsfieldii* is a small to large tree, growing up to 30 metres tall. The wood is used locally, whilst an essential oil is contained in the leaves. Range distribution of this species at Southeast Asia from Indonesia to Australia. The habitat for this species in the a canopy tree in rainforests, semi-deciduous mesophyll to notophyll vine forests, generally on alluvium, at elevations from near sea level to 200 metres. This species has an essential oil is obtained from the leaves. The wood is tough and fine grained and it is used for lances (Tropical Plants Database, 2021).

4.1.3 Species Diversity Index (H')

Based on the results obtained, species diversity index (H') in Way Canguk Research Station, Bukit Barisan Selatan National Park are as follow:

Table 5. Shannon-Wiener Species Diversity Index (H')

No	Strata	H'
1	Tree	3.30
2	Sapling	3.28

Based on the Table 5, it can be seen that WCRS has a high plant species diversity index value which are 3.30 for tree strata and 3.28 for sapling strata. This is in accordance with Fachrul (2012), species diversity index for tree and sapling indicates high level. The criteria used are H'>1 indicates low level, H' $1 \leq H' \leq 3$ indicates medium level and H>3 indicates high level of diversity. WCRS that located in the BBSNP has high value of species diversity index than another National Park. According to research conducted by Reynaldy *et al.* (2018) about plant species diversity at Bali Barat National Park, where in this area the diversity of tree species is obtained with a value of 2.63 which is included in the medium category. The plants identified consist of 121 species belonging to 15 families. The highest of dominance index was found in the species *Averhoa* sp. with a value of 14.88% and the lowest was found in the species *Melaleuca leucadendra, Eryngium foetidum, Eriogiosum rubiginosum*, *Murraya paniculata*, *Streblus asper*, and *Alstonia scholaris* with a value of 0.83%.

The high value of species diversity index in this area affected by WCRS is primary forest that located in the conservation area, Bukit Barisan Selatan National Park. So, there is regulation to utilize biodiversity in this area. And also location of this area is quite far from village that make activities of society such as illegal logging is rare. This is according to Arifiani and Mahyuni (2012), who conducted research related to the comparison of plant species diversity in the WCRS and Sukaraja Atas areas where the diversity of plant species in WCRS was higher than Sukaraja Atas. This is related to the location of the WCRS forest which is farther from residential areas so that the disturbance to the exploitation of plant species is relatively lower.

In addition, the differences in species diversity may be related to the ongoing succession process. The Sukaraja Atas forest is known as a young secondary forest so the forest restoration process has just begun. Coupled with the ongoing forest clearing for pepper and coffee plantations, the plant diversity in this area is low. On the other hand, the process of succession in the Way Canguk forest has lasted longer since the 1997 fires, so forest restoration is more advanced, characterized by higher species diversity. The plant diversity in the Canguk Way and Sukaraja Atas areas, Bukit Barisan Selatan National Park is relatively high, with common tribes including Dipterocarpaceae, Euphorbiaceae, Zingiberaceae, Meliaceae, Annonaceae, Rubiaceae, Arecaceae, Melastomataceae, Moraceae and Lauraceae. Birds are a major dispersing agent, especially for tree (Arifiani and Mahyuni, 2012).

The high value of species diversity at WCRS also because this are included in a conservation area, namely the BBSNP, which has the main function of preserving the diversity of plants and animals and their protected ecosystems so that they are safe from disturbances from the surrounding community. Indicators of the stability of a growing environment can be seen from the high level of species diversity in an area (Yastori, 2016). A community is said to have high species diversity if it is composed of many species. On the other hand, a community is said to have low species diversity if it is composed of only a few species (Indriyanto, 2010).

4.2 Estimation of Biomass and Carbon Stock

4.2.1 Biomass of Tree

Total of biomass that produce from tree strata is 748.167 ton/ha. According to the research, species from Dipterocarpaceae family have a very high amount of biomass, such as the species *Dipterocarpus humeratus* (500.02 ton/ha), followed by species *Planchonia grandis* (59.09 ton/ha), and *Metadina trichotoma* (29.90 ton/ha). Meanwhile, the lowest biomass in the tree strata was Ptychopyxis costata (0.01 ton/ha). In Figure 4 below, 10 tree species with the most biomass are as follow:

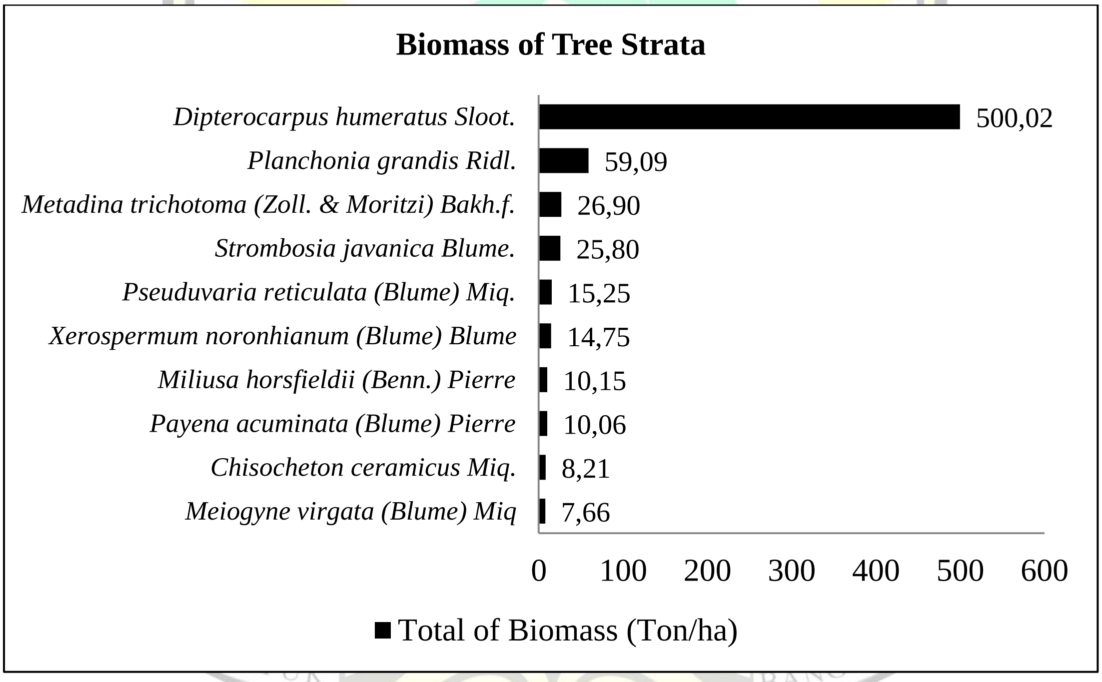

Figure. 4. Tree Species with highest Biomass

Factors that affect the biomass content of each species depends on the DBH and height of the plant. In this area, species from Dipterocarpaceae have a fairly large DBH of 10–150 cm and a height of 10–50 m. The influence of the diameter and height of trees in this area is also influenced by the condition of this area which is still classified as primary forest with high vegetation density. According to Arifanti *et al.* (2014), in general primary dryland forest is able to store carbon in greater quantities than secondary dryland forest because some of the stands have been disturbed or even lost. Fires, wood extraction, land use for farming and other events or activities in forest areas cause a reduction in the potential of biomass which has direct implications for its ability to store carbon.

Most of trees species in this study site have a high trunk diameter value. The size of the trunk diameter in trees and sapling is one of the factors that influence the amount of carbon stock it stores. This is also supported by Heriyanto and Siregar (2007), who discovered that large biomass is obtained from trees with a large diameter, resulting in a high volume produced. This is related to the process of photosynthesis. The results of photosynthesis in trees are useful in growth both in the vertical (height) and horizontal (diameter) directions, and the rest is stored in the trunk. In addition, Dharmawan and Siregar (2008) also explained that the larger the diameter of a tree, the greater the amount of CO_2 it absorbs. However, in this study, the results showed that the high value of carbon stocks was not only influenced by the diameter of the trunk, but also by the specific gravity of each tree. The amount of carbon stock between plants is different from one plant to another. The amount of carbon stock also depends on the type of plant itself, because different species have different specific gravities. The difference in the amount of organic matter content in wood with different specific gravity will affect the carbon biomass content.

4.2.1 Biomass of Sapling

Total of biomass that produce from sapling strata is 11.24 ton/ha. The highest biomass in the sapling strata is found in the plant species *Anaxagorea lanceolata* from the Annonaceae family at 2.037 ton/ha, followed by *Dillenia excelsa* (Jack) Gilg from the Dilleniaceae family at 1.231 ton/ha and *Strombosia javanica* Blume. from the Olaceae family of 1.231 ton/ha. Meanwhile, the lowest biomass in the sapling strata was *Putranjiva* sp. from the Putranjivaceae family at 0.009 ton/ha. In Figure 5 below, 10 sapling species with the most biomass are as follow:

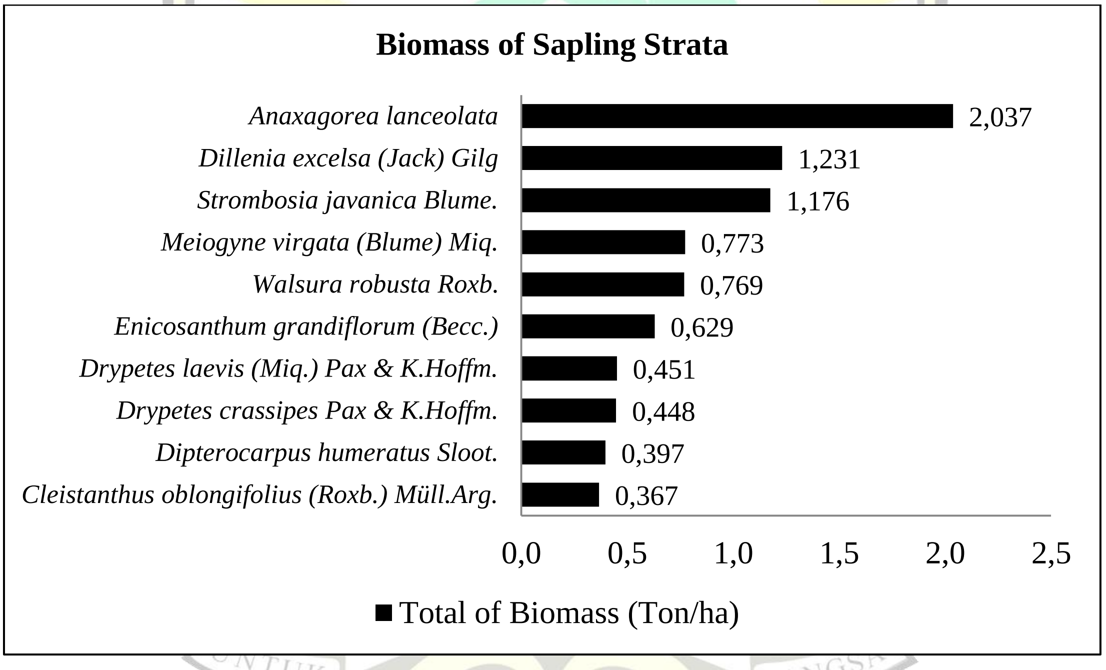

Figure. 5. Sapling Species with Highest Biomass

Morikawa (2002) stated that the high value of forest biomass is determined by diameter, specific gravity and soil fertility. For species *Anaxagorea lanceolata*, the high biomass value is not only caused by the diameter, height and density of the tree, this is also due to the large number of individual of *Anaxagorea lanceolata* which causes the biomass content to be large. *Anaxagorea lanceolata* has a high specific gravity (0.57 g/cm3) and an average tree height (5 m) so that it has the potential to provide high biomass values. The diameter and height of large trees have an effect on the high value of carbon stocks. According to Lubis *et al.* (2013), the carbon stock in a tree will increase according to the increase in the diameter of the tree and Suprihatno *et al.* (2012) stated that the taller the plant and the older the plant, the higher the carbon stock value.

According to Rugayah (2014), the *Anaxagorea* genus is plant with the habit of trees or shrubs. This genus has 26 species spread across tropical Asia, Central and South America. The distribution center of this species is reported to be in the Neotropical area from Guatemala to Peru and Rio de Jenairo in Brazil. The center of distribution of the two is in the paleotropics, namely in tropical Asia, it is thought to be from Sri Lanka to the Philippines and Indonesia.

4.2.3 Biomass of Understorey and Litter

According to this study, biomass produced from understorey strata is 0.19 ton/ha and litter is 3.87 ton/ha (Appendix 3). From that data, it can be seen that the amount of biomass produced in the litter is higher than the understorey strata. This could be due to the fact that this area is dominated by large, tall plants with a dense canopy. Understorey biomass has the lowest value because the intensity of sunlight reaching the forest floor is very low due to the dense canopy cover. The low intensity of sunlight results in the number of understorey that can grow relatively little, so that understorey plants that like open habitats cannot develop properly. This is in accordance with the opinion of Hairiah *et al.*, (2001) that the denser the tree canopy, the lower the understorey biomass due to reduced sunlight reaching the forest floor.

Litter is one component in the forest that can also store carbon. The litter formed is a contribution from the weathering of leaves and twigs as well as the wood on trees so that the more trees there are, the greater the litter source and the higher the carbon stored. The high litter biomass, apart from the fact that there were many trees with large diameters, was also thought to be caused by the fact that trees with broad leaves shed a lot of leaves, such as those in the Dipterocarpaceae family. The Way Canguk Research Station area is a primary forest with a very high diversity. So that it affects the litter production of each tree. Plant species from the Dipterocarpaceae family, which have broad and abundant leaves, dominate in this area, making the nests have the potential to store high carbon stocks. For the level of sapling and understorey, the carbon content stored is not too much when compared to the level of tree and litter.

Efrinaldi (2014) in his research on the dynamics of biomass and carbon stocks in Siberut National Park explained that the size of forest stands in the form of trees is much larger than the size of understorey and litter found on the forest floor. Trees even dominate the amount of biomass and other carbon storage pockets. Litter is sourced from branches, twigs and dead leaves from trees, understorey life on the forest floor is also controlled by trees because the sun as a source of energy to cook food for understorey is blocked by the tree canopy. This causes a large difference between the amount of biomass and carbon stocks of forest stands between understorey and litter.

Nugraha (2010) in Novriyanto *et al.* (2018) also explains what causes the amount of litter biomass to be much larger than the understorey, namely the number of trees, because the more trees there are, the more leaves, twigs, and fruit will fall, so litter accumulates on the floor. There will also be more forest. Besides that, litter also stores water for a relatively long time. On the forest floor, the more or thicker the litter that accumulates, the more difficult it will be for the understorey to grow, because it is difficult for the understorey to reach the ground. In addition, the denser the trees, the less light reaches the forest floor.

Other supporting factors besides stem diameter, height, and specific gravity, which contribute to the large potential of the above-ground carbon content in the Way Canguk Research Station Area are environmental factors of the area such as rainfall. According to Rositah *et al.* (2013), litter productivity is also influenced by vegetation and rainfall. Rainfall affects the physiology of vegetation because the higher the rainfall, the lower the fall of leaves, twigs, flowers and fruit, when the rainfall is high the humidity will increase, the evaporation of the leaves will decrease so that the leaves remain fresh and do not fall easily.

4.2.4 Total of Carbon Stock

Based on the research that had been carried out, it is found that the total of biomass and carbon stock that store at tree, sapling, understorey, and litter strata in WCRS significantly different. In Table 6, total of biomass from each carbon pools are tabulated:

Table 6. Total of Biomass and Carbon Stock

No	Strata	Biomass (ton/ha)	Carbon stock (ton/ha)
1	Tree	748.167	351.638
2	Sapling	11.24	5.28
3	Understorey	0.19	0.09
4	Litter	3.87	1.82
	Total	763.48 ton/ha	358.828 ton/ha

Based on the Table 6, it can be seen that the total amount of biomass content in the Way Research Station area of Canguk, South Bukit Barisan National Park is 763.48 ton/ha. For tree, the highest biomass value was obtained at 748.167 ton/ha, saplings of 11.24 ton/ha, understorey of 0.19 ton/ha, and litter of 3.87 ton/ha. In this data, it is also known that tree strata produce the largest amounts of biomass. While, total of carbon stored above ground level in the area of Research Station Way Canguk is 358.828 ton/ha. The highest carbon stock was obtained at the tree strata of 351.638 ton/ha and the lowest is 0.09 ton/ha for understorey strata.

Total carbon stocks in the Research Station Way Canguk of 358.828 ton/ha which is large and prove that this area has the potential to store carbon reserves and balance of CO_2 emissions in the air. Research on carbon stocks in the National Park area has been carried out by Prasetyo *et al.* (2016) on Estimating Changes in Carbon Stocks in Tambling Wildlife Nature Conservation that the total change in carbon stocks stored from 2000 to 2009 changed by - 279422 Mg (7.18%) or a decrease of 27942.2 Mg (0.72%) per year. The value of carbon loss is equivalent to the release of CO_2 from this area of 1.024.547 Mg or 102.454.7 Mg CO_2 per year. 2. Reduction of stored carbon stock is caused by conversion of primary forest, especially to secondary forest and shrubs.

Research about carbon stock using allometric equation already done before in some area. Comparison of total carbon stock in some area with different allometric equation can be seen from table below:

Table 7. Research Comparison about Carbon Stock Estimation

No	Source	Allometric Equation	Total of Carbon Stock
1	Dantas *et al.* (2021) Above and belowground carbon stock in a tropical forest in Brazil	Chave *et al.* (2014) AGB = 0.0673 x $(\rho D^2 H)^{0.976}$	267.52 Mg ha-1
2	Suryandari *et al.* (2019) Estimation of Aboveground Stored Carbon Stocks in the Arboretum Sylva of Universitas Tanjungpura	Chave *et al.* (2005) (AGB) est = $\boldsymbol{\rho}$*exp (-1.499+2.148*In(D)+0.207*(In(D))^2-0.0281*(In(D))^3)	255.55 ton/ha (living tree) and 180.42 ton/ha (Necromass)
3	Suwardi *et al.* (2013) Species Composition and Carbon Stock in Tropical Lowland Forest, Ulu Gadut, West Sumatra	Katterings *et al.* (2001) (AGB)est = 0.11 x ρ x $D^{2.62}$	241.38 ton C/ha.
4	Azham (2015) Estimation of Carbon Stock in Secondary Forest Land Cover, shrubs and thickets in Samarinda	Chave *et al.* (2005) (AGB) est = $\boldsymbol{\rho}$*exp (-1.499+2.148*In(D)+0.207*(In(D))^2-0.0281*(In(D))^3)	95.798 ton/ha (land cover), 42.667 ton/ha (shrubs) and 26.464 ton/ha (thickets).
5	Suyanto and Asyari (2021) Estimation of Carbon Reserves Above Ground Level in Liang Anggang Protected Forest Area of Banjarbaru City South Kalimantan	Chave *et al.* (2005) Y = 0.509 x $\boldsymbol{\rho}$ x DBH^2 x H	731.49 ton (Tree and understorey)

Erly *et al.* (2019) also conducted research related to species diversity and tree carbon storage at Pemerihan Resort, Bukit Barisan Selatan National Park where the result of tree carbon storage was 277.64 ton c/ha and was above the Asian humid forest threshold. This carbon storage reflects that the location is in primary dryland forest and is included in the category of High Density Forest (HK 3). Meanwhile, the types of trees found were 611 individual trees with 99 tree species in 38 tree families/tribes. The Dipterocarpaceae dominate 38%. The distribution of diameter classes includes normal forest types. Pemerihan Resort has a moderate level of tree species diversity with very stable environmental conditions (H´ of 2.70).

From the results obtained for the above-ground carbon stock value in the Way Canguk Research Station area, Bukit Barisan Selatan National Park, which is 358.828 ton/ha, this area is included in the category of High Density Forest (HK 3) according to the forest research report which has a high carbon stock that has been compiled by Golden Agri-Resources and SMART in collaboration with The Forest Trust and Greenpeace (Golden Agri-Resources and SMART, 2012). Therefore, this area must be preserved in order to maintain its potential in storing carbon stocks on the island of Sumatra.

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusions

From research that had been done can be concluded as follows:

1. The diversity of plant species at the Way Canguk Research Station, Bukit Barisan Selatan National Park is classified as high species diversity with H' = 3.30 at tree strata and H' = 3.28 at sapling strata. If a community contains a high level of biodiversity, it is considered to have high species diversity. A community, on the other hand, is said to have low species variety if it is made up of only a few species.
2. The total of above ground biomass that storage in each carbon pool in the Way Canguk Research Station area, Bukit Barisan Selatan National Park is 763.48 ton/ha and the total carbon stock is 358.828 ton/ha which is included in the category of High Density Forest (HK 3).

5.2 Recommedations

From the research that has been done, it is hoped that in the future there will be more research related to estimating carbon stocks in various types of forest ecosystems. It is also essential to conduct annual carbon stock monitoring at the Way Canguk Research Station using the most up-to-date methods, which, if assessed, are more accurate in estimating biomass and carbon stocks. Plants in the Dipterocarpaceae family, for example, must be conserved because they have a great potential for storing biomass and carbon stocks.

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APPENDICES

Appendix 1. Biomass and Carbon Stock for Tree

No	Scientific Name	Family	Biomass (Ton/ha)	Carbon Stock (Ton/ha)
1	*Aglaia aquea* (Jack) Kosterm.	Meliaceae	2.56	1.25
2	*Alangium javanicum* (Blume) Wangerin	Alangiaceae	7.20	3.53
3	*Alseodaphne sp.*	Lauraceae	0.36	0.18
4	*Aporosa arborea* (Blume) Müll.Arg.	Phyllantaceae	1.92	0.94
5	*Archidendron bubalinum* (Jack) I.C.Nielsen	Fabaceae	0.53	0.26
6	*Bridelia tomentosa* Blume	Phyllantaceae	0.57	0.28
7	*Cananga odorata* (Lam.) hook.f. & Thomson	Annonaceae	4.73	2.32
8	*Canarium denticulatum* Blume	Burseraceae	1.28	0.63
9	*Celtis rigescens* (Miq.) Planch.	Cannabaceae	4.02	1.97
10	*Chisocheton ceramicus* Miq.	Meliaceae	8.21	4.02
11	*Cleistanthus oblongifolius* (Roxb.) Müll.Arg.	Phyllantaceae	0.24	0.12
12	*Croton argyratus* Blume	Euphorbiaceae	0.99	0.48
13	*Cryptocarya sp.*	Lauraceae	0.29	0.14
14	*Dacryodes rostrata* (Blume) H.J.Lam.	Burseraceae	1.26	0.62
15	*Dehaasia microsepala* (Bl.) H.J. Lam	Lauraceae	0.68	0.33
16	*Dialium platysepalum* Baker.	Fabaceae	0.29	0.14
17	*Dillenia excelsa* (Jack) Gilg	Dilleniaceae	5.20	2.55
18	*Diospyros macrophylla* Blume	Ebenaceae	1.68	0.82
19	*Diospyros pendula* Hasselt ex Hassk.	Ebenaceae	0.77	0.38
20	*Dipterocarpus humeratus* Sloot.	Dipterocarpaceae	500.02	245.01
21	*Dracontomelon dao* (Blanco) Merr. & Rolfe	Anarcadiaceae	0.35	0.17
22	*Drypetes macrophylla* (Blume) Pax & K.Hoffm.	Putranjivaceae	1.05	0.51
23	*Dysoxylum sp.*	Meliaceae	3.36	1.65
24	*Glochidion zeylanicum* (Gaertn.) A.Juss.	Phyllantaceae	5.67	2.78
25	*Heritiera javanica* (Blume) Koesterm.	Malvaceae	0.75	0.37
26	*Ixonanthes icosandra* Jack	Ixonantaceae	1.22	0.60
27	*Madhuca pallida* (Burck) Baehni.	Sapotaceae	0.33	0.16
28	*Magnolia gigantifolia* (Miq.) Noot.	Magnoliaceae	3.70	1.82
29	*Meiogyne virgata* (Blume) Miq.	Annonaceae	7.66	3.75

30	*Metadina trichotoma* (Zoll. & Moritzi) Bakh.f	Rubiaceae	26.90	13.18
31	*Miliusa horsfieldii* (Benn.) Pierre	Annonaceae	10.15	4.97
32	*Paranephelium nitidum* King	Sapindaceae	3.66	1.79
33	*Payena acuminata* (Blume) Pierre	Sapotaceae	10.06	4.93
34	*Planchonia grandis* Ridl.	Lecythidaceae	59.09	28.95
35	*Polyalthia cauliflora* Hook.f. & Thomson	Annonaceae	3.02	1.48
36	*Polyalthia rumphii* (Blume ex Hensch.) Merrr.	Annonaceae	3.87	1.90
37	*Popowia bancana* Schff.	Annonaceae	1.82	0.89
38	*Pseuduvaria reticulata* (Blume) Miq.	Annonaceae	15.25	7.47
39	*Ptychopyxis costata* Miq.	Euphorbiaceae	0.18	0.09
40	*Quercus sp.*	Fagaceae	0.53	0.26
41	*Rinorea lanceolata* (Wall.) Kuntze	Violaceae	2.91	1.42
42	*Sindora leiocarpa* Backer ex K.Heyne & de Wit.	Fabaceae	0.54	0.27
43	*Strombosia ceylanica* Gardn.	Olacaceae	0.56	0.27
44	*Strombosia javanica* Blume.	Olacaceae	25.80	12.64
45	*Xanthophyllum flavescens* Roxb.	Polygalaceae	0.74	0.36
46	*Xerospermum noronhianum* (Blume) Blume	Sapindaceae	14.75	7.23
47	*Ziziphus angustifolia* (Miq.) Hatus. ex Steenis	Rhamnaceae	1.48	0.72
	Total		748.167	351.638

Appendix 2. Biomass and Carbon Stock for Sapling

No	Scientific Name	Family	Biomass (ton/ha)	Carbon Stock (ton/ha)
1	*Aglaia teysmanniana* (Miq.) Miq.	Meliaceae	0.31	0.15
2	*Anaxagorea lanceolate*	Annonaceae	2.04	0.96
3	*Archidendron bubalinum* (Jack) I.C.Nielsen	Fabaceae	0.03	0.02
4	*Ardisia sp.*	Primulaceae	0.16	0.07
5	*Atuna racemosa* Raf.	Chrysobalanoceae	0.03	0.02
6	*Beilschmiedia* lucidula (Miq.) Kosterm.	Lauraceae	0.08	0.04
7	*Cleistanthus oblongifolius* (Roxb.) Müll.Arg.	Phyllantaceae	0.37	0.17
8	*Dillenia excelsa* (Jack) Gilg	Dilleniaceae	1.23	0.58
9	*Dillenia sumatrana* Miq.	Dilleniaceae	0.22	0.10
10	*Diospyros ferox* Bakh.	Ebenaceae	0.04	0.02
11	*Diospyros sp.*	Ebenaceae	0.29	0.14
12	*Dipterocarpus humeratus* Sloot.	Dipterocarpaceae	0.40	0.19
13	*Dipterocarpus kunstlerii* King	Dipterocarpaceae	0.02	0.01
14	*Dracontomelon dao* (Blanco) Merr. & Rolfe	Anarcadiaceae	0.03	0.01
15	*Drypetes crassipes* Pax & K.Hoffm.	Putranjivaceae	0.45	0.21
16	*Drypetes laevis* (Miq.) Pax & K.Hoffm.	Putranjivaceae	0.45	0.21
17	*Drypetes macrophylla* (Blume) Pax & K.Hoffm.	Putranjivaceae	0.05	0.02
18	*Enicosanthum grandiflorum* (Becc.)	Annonaceae	0.63	0.30
19	*Galearia filiformis* (Blume) Boerl.	Euphorbiaceae	0.02	0.01
20	*Glycosmis chlorosperma*	Rutaceae	0.02	0.01
21	*Glycosmis pentaphylla* (Retz.) DC.	Rutaceae	0.02	0.01
22	*Hypobathrum sp.*	Rubiaceae	0.02	0.01
23	*Leea aequata* L.	Ampelidaceae	0.09	0.04
24	*Litsea angulata* Blume	Lauraceae	0.01	0.00
25	*Litsea diversifolia* Blume.	Lauraceae	0.04	0.02
26	*Lophopetalum javanicum* (Zoll.) Turcz.	Celastraceae	0.20	0.09
27	*Mallotus miquellianus*	Euphorbiaceae	0.25	0.12
28	*Meiogyne virgata* (Blume) Miq.	Annonaceae	0.77	0.36
29	*Miliusa horsfieldii* (Benn.)	Annonaceae	0.01	0.01

	Pierre.			
30	*Myristica sp.*	Myristicaceae	0.01	0.01
31	*Neouvaria sp.*	Annonaceae	0.11	0.05
32	*Polyalthia lateriflora* (Blume) Kurz.	Annonaceae	0.01	0.01
33	*Popowia bancana* Schff.	Annonaceae	0.28	0.13
34	*Popowia pisocarpa* (Blume) Endl. ex Walp.	Annonaceae	0.10	0.05
35	*Pseuduvaria reticulate* (Blume) Miq.	Annonaceae	0.11	0.05
36	*Pseuduvaria sp.*	Annonaceae	0.02	0.01
37	*Psychotria malayana* Jack.	Rubiaceae	0.16	0.08
38	*Putranjiva sp.*	Putranjivaceae	0.01	0.00
39	*Rinorea lanceolata* (Wall.) Kuntze	Violaceae	0.12	0.06
40	*Strombosia javanica* Blume.	Olaceae	1.18	0.55
41	*Syzygium* racemosum (Blume) DC.	Myrtaceae	0.03	0.02
42	*Trigonostemon laevigatus* Müll. Arg.	Euphorbiaceae	0.05	0.02
43	*Walsura robusta* Roxb.	Meliaceae	0.77	0.36
	Total		11.24	5.28

Appendix 3. Biomass and Carbon Stock for Understorey and Litter

a. Understorey

Plot	BB (g)	BB Total (g)	BK (g)	BK Total (g)
2E400-01	228	229	58.63	58.89
2E400-02	78	61	25.74	20.13
2E400-03	159	158	53.89	53.55
2E400-04	153	145	65.38	61.96
2E400-05	294	301	130.12	133.22
C400-06	300	560	72.22	134.81
C400-07	89	77	24.56	21.25
C400-08	226	226	64.52	64.52
C400-09	80	79	18.02	17.79
C400-10	0	0	0	0.00
I200-11	300	609	50.84	103.21
I200-12	300	367	127.05	155.42
I200-13	263	265	87.4	88.06
I200-14	17	17	0.64	0.64
I200-15	157	161	58.8	60.30
O400-16	300	533	71.22	126.53
O400-17	300	296	93.41	92.16
O400-18	300	454	89.23	135.03
O400-19	172	173	53.39	53.70
O400-20	300	480	100.05	160.08

Total:
Biomass 0.19 ton/ha
Carbon stock 0.09 ton/ha

b. Litter

Plot	BB (g)	BB Total (g)	BK (g)	BK Total (g)
2E400-01	300	4512	110.99	1669.29
2E400-02	300	5173	106.01	1827.97
2E400-03	300	4626	105.88	1632.67
2E400-04	300	5155	103.18	1772.98
2E400-05	300	4432	107.05	1581.49
C400-06	300	3405	104.41	1185.05
C400-07	300	2683	102.61	917.68
C400-08	300	3205	110.48	1180.29
C400-09	300	6155	139.95	2871.31
C400-10	300	6831	143.04	3257.02
I200-11	300	1245	105.28	436.91
I200-12	300	4430	117.56	1735.97
I200-13	300	3261	114.87	1248.64
I200-14	300	2315	115.03	887.65
I200-15	300	4343	139.5	2019.50
O400-16	300	2705	126.65	1141.96
O400-17	300	2068	137.18	945.63
O400-18	300	3429	116.88	1335.94
O400-19	300	3070	140.81	1440.96
O400-20	300	4157	134.72	1866.77
Total:				
Biomass		3.87 ton/ha		
Carbon Stock		1.82 ton/ha		

Appendix 4. Data of Environmental Factors Measurenment

a. Rainfall (mm)

Bulan	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Jan	250	576	427	606	357	290	165	314	440	425	476
Feb	204	256	253	147	304	410	325	302	162	230	206
Mar	414	382	203	232	252	678	364	376	480	291	258
Apr	239	353	243	274	350	205	342	256	344	123	150
May	199	138	270	115	52	328	57	59	112	342	135
Jun	112	51	380	219	16	236	127	256	20	269	92
Jul	55	56	196	337	34	182	176	10	38	142	11
Aug	3	12	128	136	19	245	182	81	0.2	52	127
Sep	4	11	135	65	1	437	470	150	4	155	131
Okt	127	471	220	138	0	480	928	195	2	428	
Nov	666	593	489	634	365	596	541	486	96	488	
Des	387	543	277	535	709	535	421	616	269	704	
Total	2660	3442	3221	3438	2459	4620	4099	3102	1966	3649	
Rerata bulanan	222	287	268	286	205	385	342	258	164	396	

Daily Ranfall when Data Collection at Field

Date	Rainfall (mm)
29/09/2021	0
30/09/2021	24.4
01/10/2021	2.6
02/10/2021	0.4
03/10/2021	0
04/10/2021	4
05/10/2021	11.6
06/10/2021	13
07/10/2021	36.6
08/10/2021	15
09/10/2021	0.9
10/10/2021	0.3
11/10/2021	43
12/10/2021	24.9
13/10/2021	0.2
14/10/2021	34.4
15/10/2021	71.6
16/10/2021	0.2

b. Temperature

Date	Temperature (C°)	
	Min	Max
29/09/2021	22.5	38.5
30/09/2021	22.5	36.5
01/10/2021	21.5	37
02/10/2021	22	29
03/10/2021	22	35.5
04/10/2021	22.5	36
05/10/2021	21	30
06/10/2021	21	35
07/10/2021	21.5	25
08/10/2021	22	31
09/10/2021	22	39
10/10/2021	21.5	35
11/10/2021	22.5	39
12/10/2021	22	35
13/10/2021	22	38
14/10/2021	22	38
15/10/2021	22	38
16/10/2021	22	34

c. Altitude

Elevation at Way Canguk Research Station between 15-70 mdpl (based on DEM SRTM 30 m).

Appendix 5. Data of Vegetation Analysis

a. Tree

No	Scientific Name	Family	KR (%)	FR (%)	DR (%)	INP (%)	H’
1	*Aglaia aquea* (Jack) Kosterm.	Meliaceae	1.08	1.28	0.62	2.98	0.046
2	*Alangium javanicum* (Blume) Wangerin	Alangiaceae	1.08	1.28	1.35	3.71	0.054
3	*Alseodaphne* sp.	Lauraceae	1.08	1.28	0.14	2.50	0.040
4	*Aporosa arborea* (Blume) Müll.Arg.	Phyllantaceae	1.08	1.28	0.60	2.96	0.046
5	*Archidendron bubalinum* (Jack) I.C.Nielsen	Fabaceae	1.08	1.28	0.27	2.63	0.042
6	*Bridelia tomentosa* Blume	Phyllantaceae	1.08	1.28	0.28	2.64	0.042
7	*Cananga odorata* (Lam.) hook.f. & Thomson	Annonaceae	1.08	1.28	1.68	4.03	0.058
8	*Canarium denticulatum* Blume	Burseraceae	2.15	2.56	0.29	5.01	0.068
9	*Celtis rigescens* (Miq.) Planch.	Cannabaceae	1.08	1.28	1.20	3.56	0.053
10	*Chisocheton ceramicus* Miq.	Meliaceae	3.23	3.85	2.97	10.04	0.114
11	*Cleistanthus oblongifolius* (Roxb.) Müll.Arg.	Phyllantaceae	1.08	1.28	0.10	2.46	0.039
12	*Croton argyratus* Blume	Euphorbiaceae	2.15	2.56	0.33	5.05	0.069
13	*Cryptocarya* sp.	Lauraceae	1.08	1.28	0.13	2.48	0.040
14	*Dacryodes rostrata* (Blume) H.J.Lam.	Burseraceae	1.08	1.28	0.35	2.70	0.042
15	*Dehaasia microsepala* (Bl.) H.J. Lam	Lauraceae	1.08	1.28	0.25	2.61	0.041
16	*Dialium platysepalum* Baker.	Fabaceae	1.08	1.28	0.09	2.45	0.039
17	*Dillenia excelsa* (Jack) Gilg	Dilleniaceae	3.23	3.85	1.64	8.71	0.103
18	*Diospyros macrophylla* Blume	Ebenaceae	1.08	1.28	0.41	2.77	0.043
19	*Diospyros pendula* Hasselt ex Hassk.	Ebenaceae	1.08	1.28	0.32	2.68	0.042
20	*Dipterocarpus humeratus* Sloot.	Dipterocarpacea	12.90	7.69	46.52	67.11	0.335
21	*Dracontomelon dao* (Blanco) Merr. &	Anarcadiaceae	1.08	1.28	0.11	2.47	0.040

	Rolfe						
22	*Drypetes macrophylla* (Blume) Pax & K.Hoffm.	Putranjivaceae	1.08	1.28	0.26	2.61	0.041
23	*Dysoxylum* sp.	Meliaceae	2.15	1.28	0.90	4.33	0.061
24	*Glochidion zeylanicum* (Gaertn.) A.Juss.	Phyllantaceae	2.15	2.56	1.77	6.48	0.083
25	*Heritiera javanica* (Blume) Koesterm.	Malvaceae	1.08	1.28	0.17	2.53	0.040
26	*Ixonanthes icosandra* Jack	Ixonantaceae	2.15	2.56	0.62	5.33	0.072
27	*Madhuca pallida* (Burck) Baehni.	Sapotaceae	1.08	1.28	0.12	2.48	0.040
28	*Magnolia gigantifolia* (Miq.) Noot.	Magnoliaceae	1.08	1.28	1.06	3.42	0.051
29	*Meiogyne virgata (*Blume) Miq.	Annonaceae	5.38	5.13	2.24	12.75	0.134
30	*Metadina trichotoma* (Zoll. & Moritzi) Bakh.f	Rubiaceae	1.08	1.28	3.74	6.09	0.079
31	*Miliusa horsfieldii* (Benn.) Pierre	Annonaceae	2.15	2.56	1.93	6.65	0.084
32	*Paranephelium nitidum* King	Sapindaceae	1.08	1.28	0.61	2.96	0.046
33	*Payena acuminata* (Blume) Pierre	Sapotaceae	1.08	1.28	1.78	4.13	0.059
34	*Planchonia grandis* Ridl.	Lecythidaceae	1.08	1.28	7.21	9.57	0.110
35	*Polyalthia cauliflora* Hook.f. & Thomson	Annonaceae	3.23	3.85	0.90	7.98	0.096
36	*Polyalthia rumphii* (Blume ex Hensch.) Merrr.	Annonaceae	1.08	1.28	1.38	3.73	0.055
37	*Popowia bancana* Schff.	Annonaceae	3.23	3.85	0.89	7.96	0.096
38	*Pseuduvaria reticulata* (Blume) Miq.	Annonaceae	4.30	3.85	2.56	10.71	0.119
39	*Ptychopyxis costata* Miq.	Euphorbiaceae	1.08	1.28	0.09	2.45	0.039
40	*Quercus* sp.	Fagaceae	1.08	1.28	0.15	2.50	0.040
41	*Rinorea lanceolata* (Wall.) Kuntze	Violaceae	2.15	2.56	0.86	5.57	0.074
42	*Sindora leiocarpa* Backer ex K.Heyne & de Wit.	Fabaceae	1.08	1.28	0.17	2.53	0.040
43	*Strombosia ceylanica* Gardn.	Olacaceae	1.08	1.28	0.13	2.49	0.040

44	*Strombosia javanica* Blume.	Olacaceae	12.90	10.26	7.01	30.17	0.231
45	*Xanthophyllum flavescens* Roxb.	Polygalaceae	1.08	1.28	0.18	2.54	0.040
46	*Xerospermum noronhianum* (Blume) Blume	Sapindaceae	3.23	1.28	3.09	7.60	0.093
47	*Ziziphus angustifolia* (Miq.) Hatus. ex Steenis	Rhamnaceae	1.08	1.28	0.54	2.89	0.045
						300.00	3.304

b. Sapling

No	Scientific Name	Family	KR (%)	FR (%)	DR (%)	INP (%)	H’
1	*Aglaia teysmanniana* (Miq.) Miq.	Meliaceae	0.69	1.27	1.70	3.66	0.05
2	*Anaxagorea lanceolate*	Annonaceae	30.56	6.33	23.86	60.75	0.32
3	*Archidendron bubalinum* (Jack) I.C.Nielsen	Fabaceae	0.69	1.27	0.63	2.59	0.04
4	*Ardisia* sp.	Primulaceae	3.47	1.27	1.82	6.56	0.08
5	*Atuna racemosa* Raf.	Chrysobalanoceae	0.69	3.80	0.36	4.85	0.07
6	*Beilschmiedia* lucidula (Miq.) Kosterm.	Lauraceae	0.69	1.27	0.85	2.81	0.04
7	*Cleistanthus oblongifolius* (Roxb.) Müll.Arg.	Phyllantaceae	1.39	2.53	2.79	6.71	0.09
8	*Dillenia excelsa* (Jack) Gilg	Dilleniaceae	6.94	2.53	10.35	19.83	0.18
9	*Dillenia sumatrana* Miq.	Dilleniaceae	0.69	1.27	1.30	3.26	0.05
10	*Diospyros ferox* Bakh.	Ebenaceae	0.69	1.27	0.36	2.32	0.04
11	*Diospyros* sp.	Ebenaceae	1,39	2.53	2.19	6,11	0.08
12	*Dipterocarpus humeratus* Sloot.	Dipterocarpaceae	2.08	2.53	3.53	8.14	0.10
13	*Dipterocarpus kunstlerii* King	Dipterocarpaceae	0.69	1.27	0.26	2.22	0.04
14	*Dracontomelon dao* (Blanco) Merr. & Rolfe	Anarcadiaceae	1.39	2.53	0.74	4.66	0.06
15	*Drypetes crassipes* Pax & K.Hoffm.	Putranjivaceae	1.39	1.27	3.21	5.87	0.08
16	*Drypetes laevis* (Miq.) Pax & K.Hoffm.	Putranjivaceae	2.78	3.80	3.19	9.76	0.11
17	*Drypetes macrophylla* (Blume) Pax & K.Hoffm.	Putranjivaceae	0.69	1.27	0.41	2.37	0.04
18	*Enicosanthum grandiflorum* (Becc.)	Annonaceae	1.39	2.53	4.42	8.34	0.10

19	*Galearia filiformis* (Blume) Boerl.	Euphorbiaceae	0.69	1.27	0.34	2.30	0.04
20	*Glycosmis chlorosperma*	Rutaceae	1.39	2.53	0.45	4.37	0.06
21	*Glycosmis pentaphylla* (Retz.) DC.	Rutaceae	0.69	1.27	0.23	2.19	0.04
22	*Hypobathrum sp.*	Rubiaceae	0.69	1.27	0.28	2.24	0.04
23	*Leea aequata* L.	Ampelidaceae	1.39	1.27	1.07	3.72	0.05
24	*Litsea angulata* Blume	Lauraceae	0.69	1.27	0.20	2.16	0.04
25	*Litsea diversifolia* Blume.	Lauraceae	0.69	1.27	0.43	2.39	0.04
26	*Lophopetalum javanicum* (Zoll.) Turcz.	Celastraceae	1.39	2.53	1.71	5.63	0.07
27	*Mallotus miquellianus*	Euphorbiaceae	9.03	10.13	4.57	23.72	0.20
28	*Meiogyne virgata* (Blume) Miq.	Annonaceae	2.08	3.80	4.51	10.39	0.12
29	*Miliusa horsfieldii* (Benn.) Pierre.	Annonaceae	0.69	1.27	0.17	2.13	0.04
30	*Myristica sp.*	Myristicaceae	0.69	1.27	0.23	2.19	0.04
31	*Neouvaria sp.*	Annonaceae	0.69	1.27	1.11	3.07	0.05
32	*Polyalthia lateriflora* (Blume) Kurz.	Annonaceae	0.69	1.27	0.24	2.20	0.04
33	*Popowia bancana* Schff.	Annonaceae	5.56	6.33	5.19	17.07	0.16
34	*Popowia pisocarpa* (Blume) Endl. ex Walp.	Annonaceae	2.08	2.53	1.75	6.37	0.08
35	*Pseuduvaria reticulate* (Blume) Miq.	Annonaceae	2.08	3.80	0.89	6.77	0.09
36	*Pseuduvaria sp.*	Annonaceae	1.39	2.53	0.37	4.29	0.06
37	*Psychotria malayana* Jack.	Rubiaceae	2.08	1.27	1.90	5.25	0.07
38	*Putranjiva sp.*	Putranjivaceae	0.69	1.27	0.18	2.14	0.04
39	*Rinorea lanceolata* (Wall.) Kuntze	Violaceae	1.39	2.53	0.98	4.90	0.07
40	*Strombosia javanica* Blume.	Olaceae	2.78	2.53	7.02	12.33	0.13

41	*Syzygium* racemosum (Blume) DC.	Myrtaceae	0.69	1.27	0.30	2.26	0.04
42	*Trigonostemon laevigatus* Müll. Arg.	Euphorbiaceae	0.69	1.27	0.56	2.52	0.04
43	*Walsura robusta* Roxb.	Meliaceae	1.39	2.53	3.34	7.26	0.09
						300.00	3.28

Appendix 6. Research Documentation

Measuring DBH of Tree

Measuring Weight of Litter

Vegetation Condition at Way Canguk Research Station

Overview of Understorey and Litter

Canopy Cover at Way Canguk Research Station

Dryed the sample use oven

Measure weight of litter after dry

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PLANT SPECIES DIVERSITY AND ESTIMATION OF ABOVEGROUND CARBON STOCK AT WAY CANGUK RESEARCH STATION, BUKIT BARISAN SELATAN NASIONAL PARK

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