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The Potential of Carbon Sequestration in the Sanctuary Maleo Hungayono Resort TulaboloPinogu Nani Wartabone Bogani National Park Area

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ABSTRACT
A forest is a unified ecosystem in the form of an expanse of land containing biological natural resources. It is dominated by trees in one natural environment and another so that they cannot be separated. Forests play an important role in maintaining the balance of carbon dioxide in the atmosphere. Their plants can absorb carbon dioxide from the air during the photosynthesis process so they play an important role in maintaining climate balance. The Maleo Hungayono Sanctuary is a place for endemic animals including forests in the Bogani Nani Wartabone National Park area which cannot produce wood, so what will be the strength of the economic value of the TNBNW area is environmental services, including carbon. This research aims to determine the potential for carbon uptake in the Maleo Hungayono Sanctuary, Bogani Nani Wartabone National Park Area. The research results show that the highest biomass value at the research location is at the tree level with a total carbon uptake of 16,588.26 tons/ha; at pole level with total carbon uptake of 722.65 tonnes/ha; at the sapling level with a total carbon uptake of 63.91 tonnes/ha.

Keywords: Carbon potential, Forest, Maleo Hungayono Sanctuary

1. INTRODUCTION

Indonesian forests are one of the forests that play an important role in maintaining the world's environmental ecosystem (Baderan, 2017). Forests are renewable natural resources, natural resources that will continue to exist and have an important role in the lives of all living things. The definition of forest according to the Basic Forestry Law no. 41 of 1999(UU 41 1999) concerning forestry, namely that a forest is a unified ecosystem in the form of an expanse of land containing biological natural resources dominated by trees in one natural environment and another so that they cannot be separated. Forest ecosystems play an important role in maintaining the balance of carbon dioxide in the atmosphere, because forest plants can absorb carbon dioxide from work during the photosynthesis process, thus playing a role in maintaining climate balance, this is in line with the statement of (Sutrisna et al., 2018) which states that forests have a very important role in life is as a natural resource and provides socio-economic and environmental functions. According to (Mitchard, 2018) tropical rainforests will have very high levels of biodiversity, with plants and animals interacting with each other. The diversity of species that can be found includes trees, shrubs, shrubs, moss, fungi, ferns, epiphytes, and even microorganisms. Forests are the only safe, natural and currently available system for capturing and storing carbon on a large scale. Through the process of photosynthesis, trees absorb carbon dioxide (CO^2) from the atmosphere, if there is an excess amount of carbon dioxide it will contribute to climate change. This is in line with Mitchard's statement, (Mitchard, 2018) which states that forests are natural carbon storage spaces, although some analysts suggest carbon capture and storage using technology, this technology is quite expensive and has not been proven to exist. Forests are the only safe, natural, and currently available system for capturing and storing carbon on a large scale. Through the process of photosynthesis, trees absorb carbon dioxide (CO_2) from the atmosphere, if there is an excess amount of carbon dioxide it will contribute to climate change.

Climate change is characterized by an increase in temperature, heat, changes in rainfall patterns and an increase in extreme events such as floods, droughts, heat waves and storms caused by the increase in carbon dioxide (CO_2) gas since the era of the industrial revolution (UNEP, 2007). (UNEP [United Nations Environment Programme], 2007) says that the concentration of CO^2 in the atmosphere before the industrial revolution in 1780 was 280 ppm. Climate change can be interpreted as long-term changes in temperature and weather patterns. Problems can start from economic processes that do not take into account environmental impacts, resulting in global temperatures increasing from year to year (Prakoso et al., 2019) According to Unite, 2022, climate change became increasingly rapid in the 1800s due to human change, where the main trigger was the burning of fossil fuels such as natural gas, coal and petroleum which are widely used in industry, this is due to burning Fossil fuels release greenhouse gases (GHGs) that capture the sun's heat and increase the earth's temperature. It is feared that climate change will have an impact on the socio-economic life of countries in the world (Hindarto&Samsyanugraha, 2018). Facing this problem, the international world is trying to stabilize the concentration of gases that cause greenhouse gases through a United Nations (UN) agreement on climate change, the United Nations for Climate Change Convention (UNFCC). This convention has provided recommendations to support developing countries in reducing emissions from deforestation and degradation, known as the Reduced Emissions From Deforestation and Degradation (REDD) program. REDD is a mechanism for reducing greenhouse gas emissions by providing compensation to parties who prevent deforestation and forest degradation, namely carbon trading (Baderan& Dewi Wahyuni K., 2017). Carbon trading is a form of market-based mechanism for mitigation and adaptation efforts to the impacts of climate change. Carbon trading is the activity of buying and selling carbon credit certificates where the commodity being traded is not carbon/gas in the form of pollutants in the atmosphere, but rather all efforts to control or reduce greenhouse gases in the atmosphere. This is based on a carbon credit certificate which contains evidence of efforts to reduce/reduce air emissions through certain projects or activities to reduce greenhouse gas emissions (Tampubolon, 2022) The United States Environmental Protection Agency's Office of Air and Radiation or what was then called the National Air Pollution Control Administration introduced a mathematical mechanism to calculate sources of greenhouse gas emissions from carbon trading. This calculation shows that reducing emissions through carbon trading techniques is indeed more effective and cost-effective than switching industry to low-carbon technology. This term initially gave rise to the concept of cap and trade (Humaira, 2021). Accurate information regarding forest carbon stored in biomass is very important to describe the state of forest ecosystems with the aim of managing forest resources sustainably in an economically and ecologically feasible manner. This information is an important input for developing strategies for reducing greenhouse gas (GHG) emissions. In particular, national CO_2 emissions, especially CO_2 from tropical rainforests. Carbon dioxide (CO_2) is one of the main constituents of the greenhouse gas layer when its concentration has increased by 40% compared to the pre-industrial era. The increase in emissions occurs due to industrial processes fueled by oil and gas and deforestation and forest degradation (Manese et al., 2023) The increase in carbon dioxide (CO_2) gas emissions in the atmosphere due to anthropogenic events has occurred since after the industrial revolution and tends to increase from year to year until now (Hairiah K & Rahayu S., 2007). Tropical rain forests in the Bogani Nani Wartabone National Park include lowland and mountain forest ecosystems. below, because this forest is strongly influenced by tropical climate conditions, the Hungarian Forest can be said to be a tropical rain forest with a special ecosystem, with the interconnectedness of the constituent components as an integrated unit.

Bogani Nani Wartabone National Park is an area of tropical forest vegetation that was designated as a national park in 1991, located on the Minahasa Peninsula on the border between the provinces of Gorontalo and North Sulawesi. Bogani Nani Wartabone is the largest terrestrial national park in Sulawesi, with an area of 282,008,757. Commonly found plants include cempaka, ylang ylang, agates and ornamental plants (TNBNW, 2010). Apart from having a wealth of flora and fauna, TNBNW also has natural potential such as the Hungayono waterfall, hot springs, rock caves and Hungayono stalactites, the Maleo Hungayono bird habitat, and the natural panorama (landscape) of Peapata Hill. However, there are three important species that are better known in this field: maleo birds, anoa birds, and hog deer (Nurhamidin et al., 2020)

The Maleo Hungayono Sanctuary, which is a place to protect endemic animals, is a forest in the TNBNW area that cannot produce wood, so what will be the strength of the economic value of the TNBNW area is environmental services, including carbon. This is because carbon trading instruments have recently used National Park areas as a very promising environmental service.

2. RESEARCH METHOD

The research was conducted at the MaleoHungayono Sanctuary, TulaboloPinogu Resort, Bogani Nani Wartabone National Park Area. Geographically, the research location coordinates 0°30.293' N, 123°17.372' E (Primary Data, 2024). Details of the geographical location of the research are shown in map form in Figure 1 bellow.

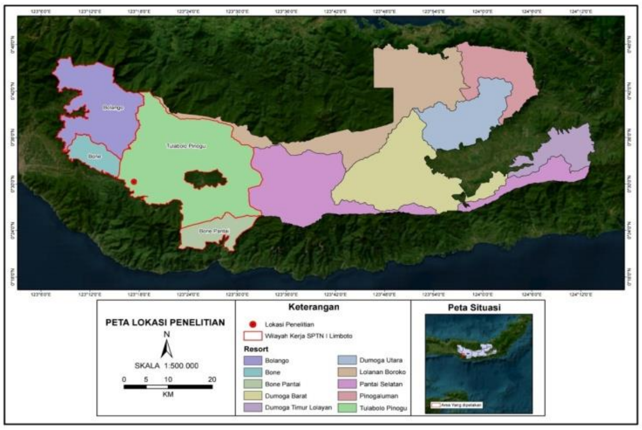

Figure 1. Geographic location of research

The method used in this research is quantitative descriptive, namely a survey method and data collection techniques using non-destructive sampling methods. This method is done by measuring the height or diameter of the tree and estimating biomass using the allometric equation (Sutaryo, 2009). This sampling method without harvesting was carried out because the Hungarian natural forest is a forest that is protected, so data collection techniques were used without harvesting so as not to damage and disturb the sustainability of the protected forest. The data collection method begins with sampling using simple random sampling. The total area is determined using the formula commonly used in forest inventories, namely the approach of Indrayanto (2012): To determine the sampling intensity, IS 10% is used, for forest groups with an area of 1,000 ha or more, the sampling intensity used should be 2%, whereas if less than 1,000 hectares, sampling intensity between 5% and 10%. Based on these specifications, a sampling intensity of 10% was used because the area to be studied was 2 ha. The sampling intensity (SI) used was 10%, sample size of the research area: 2 ha x 10% = 0.2 ha (2000 m^2), area of the tree observation plot: 20m x 20m = 400 m^2, pole: 10m x 10m =

100m², stakes: 5m x 5m = 25 m², The number of sample plots used is 2000/400 = 5 plots, The number of lanes made is 1 lane.

Primary data collection is data obtained directly in the field using a survey method in the form of local tree names, number of trees, and diameter at adult chest height (dbh). Measurement of tree biomass, poles and saplings is carried out based on the allometric equation (dbh> 1 cm) by measuring the diameter of the tree. Secondary data was collected in the form of the Latin name of the tree and the specific gravity of the wood. In each plot, the number of species and the number of individuals found in the plot were counted and recorded, the trunk circle at 135 cm or breast height was recorded. Biomass analysis is calculated based on the allometric equation (Lestari &Rahadian 2017).

From the circumference of the stem you can find the vassal area (cross-sectional area of the stem) using the formula: Circumference of the stem = $2\pi r$ Basal Area π r^2 (r = radius)
Plotting can be done representatively from an area of 2 hectares. An illustration of plot placement is as follows

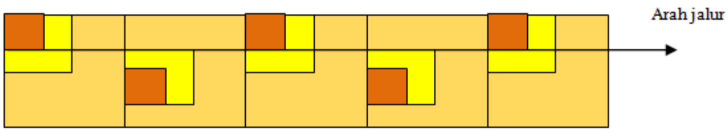

Figure 2. Checkered Line Method Design (Kusmana 1997)
Note :
Sub plot for Stake (plot 5 m x 5 m)
Sub plot for pole (plot 10 m x 10 m)
Main plot for size tree (20 m x 20m)

Data analysis techniques consist of:

1) Calculation of tree biomass, poles and saplings. Calculate biomass using an allometric equation that corresponds to the characteristics of the measurement location including climate zone, forest type, and if possible the name of the type or group of species.
2) Estimation of standing biomass for branching tree species using the formula:
   $W = 0.11\ D^{2,62}$ (Kattering*et al.*, 2001).
   Information :
   W = Biomass (Kg/tree)
   D = Diameter at chest height (cm)
3) To obtain the total biomass value, use the formula Hairiah et al., 2011: Total biomass of all trees = B1+B2+B3+………..+Bn.
4) Calculation of carbon reserves using the Brown formula, 1997:
   C = B x 0.5
   Information :
   C: Amount of carbon storage (tons/ha)
   B : Standing biomass (tons/ha)
   0.5 : Conversion factor for carbon estimation
5) Calculation of carbon dioxide uptake using the formula (Brown, 1997):absorptionCO^2=
   $\frac{ton}{ha} = \frac{bmr\ CO2}{bmr\ C}$ xcontent C
   Information :
   CO^2 :uptake carbondioxide
   RMWCO^2 :contentRelative molecular weight $CO^2$is 44
   RMW :Relative atomic molecular weight is 12

3. FINDING AND ANALYSIS

Based on the identification, it was found that there were 22 types of trees at the research location seen from the tree, pole and sapling levels, namely *Ficus variegata, Cananga orodata, Vitex copassus, Garuga florbunda, Pangium edule, Octomeles sumantrana, Pometia pinnata, Pterocymbium javanicum, Arenga pinnata, Dracontomelon Dao, Koordensiodendron pinnatum, Diospyros celebica, Palaquium obovatum, Syzygium litorale, Macaranga Sp., Dendrocnide microstigma, Endospermum peltatum, Tricalysia singularis, Pimelodendron ambonicum, Magnolia champaka, Horsfieldia bivalvis, Streblussasper, Kleinhovia hospital L., Planchonia valida, Sterculia insularis.*

Based on the calculation results, the highest carbon uptake value at the research location was at the tree level, namely 16,588.26 tons/ha. Then at the pole level, it was 722.65 tons/ha, and the lowest was at the stake level, namely 63.91 tons/ha. This is because the tree stratum contains 35 individuals with a total of 17 species, compared to the pole stratum which only has 32 individuals with a total of 9 species, and the sapling stratum which only has 26 individuals with a total of 12 species.

The total value and Carbon Uptake in each tree stratum with different types of species with the values contained in the tree, pole and sapling strata, for each observation plot are presented in the form of the following table.

3.1. Tree Level Carbon Uptake Potential

Table 1. Total Biomass and carbon uptake at tree level

No.	Plot	kinds	K	D	Biomassa (Kg/Plot)	Biomassa total (400 m^2)	C	Uptake CO2 (kg/tree)	CO2 Sanctuary (ton)
1	1	*Magnolia champaka* L.	75,79	24,14	2657,97	9048,14	1328,99	4872,95	16588,26
2		*Sterculia insularis*	43,63	13,89					
3		*Palaquiumobovatum*	74,84	23,83					
4		*Kleinhovia hospital* L.	39,8	12,68					
5		*Octomelessumantrana*	46,81	14,91					
6		*Kleinhovia hospital* L.	40,44	12,88					
7		*Pometia pinnata*	34,71	11,05					
8		*Diospyros celebica*	35,66	11,36					
9		*Pometia pinnata*	49,68	15,82					
10		*Ficus variegata*	104,14	33,17					
11	2	*Cananga Orodata*	33,43	10,65	696,12		348,06	1276,21	
12		*Cananga Orodata*	47,13	15,01					
13		*Arenga pinnata*	37,26	11,87					
14		*Cananga Orodata*	55,41	17,65					
15		*Cananga Orodata*	31,21	9,94					
16		*Cananga Orodata*	41,08	13,08					
17		*Dracontomelondao*	41,71	13,28					
18	3	*Pangiumedule*	46,81	14,91	700,85		350,43	1284,9	
19		*Dracontomelondao*	51,59	16,43					
20		*Tricalysiasingularis*	54,14	17,24					

No.	Plot	kinds	K	D	Biomassa (Kg/Plot)	Biomassa total (400 m^2)	C	Uptake CO2 (kg/tree)	CO2 Sanctuary (ton)
21		*Cananga Orodata*	51,27	16,33					
22		*Cananga Orodata*	31,21	9,94					
23	4	*Syzygiumlitorale*	35,03	11,16	2610,42		1305,21	4785,76	
24		*Ficus variegata*	93,94	29,92					
25		*Syzygiumlitorale*	32,48	10,34					
26		*Ficus variegata*	89,17	28,4					
27		*Ficus variegata*	91,4	29,11					
28		*Garuga floribunda*	51,27	16,33					
29		*Kayu Kambing*	35,66	11,36					
30	5	*Ficus variegata*	45,85	14,6	2382,79		1191,39	4368,44	
31		*Horsfieldabivalvis*	91,4	29,11					
32		*Cananga Orodata*	42,63	13,58					
33		*Dendrocnidemicrostigma*	87,26	27,79					
34		*Horsfieldabivalvis*	75,15	23,93					
35		*Cananga Orodata*	63,05	20,08					

Source :Primary Data, 2024

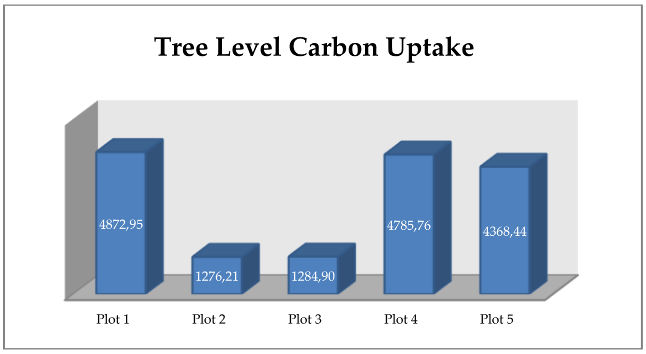

Figure 3. Graph of CO_2 Uptake at Tree Level in each plot

Based on the calculation results for total biomass and total carbon content at the tree level, the one with the highest carbon uptake value is in plot 1 with a total biomass of 2657.97 Kg/tree, having 10 individuals, with a carbon uptake of 4,872.95 Kg/Tree . With total carbon uptake at tree level of 16,588.26 tonnes/ha

3.1. Pole Level Carbon Uptake Potential

Table 2. Total Biomass and carbon uptake at pile level

No	Plot	Kinds	K	D	Biomassa Total (Kg/plot)	Biomassa Total (100 m²)	C (ton/ha)	Uptake CO_2 (kg/tree)	Total CO_2 Sanctuary (ton)
1	1	*Kleinhovia hospital* L.	11,46	3,65	52,74	394,17	26,37	96,69	722,65
2		*Kleinhovia hospital* L.	20,7	6,59					
3		*Kleinhovia hospital* L.	12,42	3,96					
4		*Cananga Orodata*	21,97	7					

No	Plot	Kinds	K	D	Biomassa Total (Kg/plot)	Biomassa Total (100 m²)	C (ton/ha)	Uptake CO_2 (kg/tree)	Total CO_2 Sanctuary (ton)
5		*Kleinhovia hospital* L.	15,92	5,07					
6		*Vitex copassus*	12,73	4,05					
7	2	*Sterculia insularis*	11,46	3,65	65,44		32,72	119,97	
8		*Cananga Orodata*	17,19	5,47					
9		*Kleinhovia hospital* L.	22,45	7,15					
10		*Cananga Orodata*	12,73	4,05					
11		*Pangiumedule*	16,56	5,27					
12		*Cananga Orodata*	23,24	7,4					
13	3	*Kleinhovia hospital* L.	22,61	7,2	110,94		55,47	203,38	
14		*Kleinhovia hospital* L.	18,15	5,78					
15		*Kleinhovia hospital* L.	25,47	8,11					
16		*Kleinhovia hospital* L.	14,69	4,68					
17		*Cananga Orodata*	29,61	9,43					
18		*Planchoniavalida*	16,56	5,27					
19	4	*Horsfieldabivalvis*	19,42	6,18	46,06		23,03	84,44	
20		*Kleinhovia hospital* L.	11,78	3,75					
21		*Kleinhovia hospital* L.	12,73	4,05					
22		*Kleinhovia hospital* L.	15,28	4,87					
23		*Horsfieldabivalvis*	17.51	5,58					
24		*Kleinhovia hospital* L.	16,4	5,22					
25	5	*Planchoniavalida*	12,1	3,85	119		59,5	218,17	
26		*Kleinhovia hospital* L.	17,83	5,68					
27		*Kleinhovia hospital* L.	13,69	4,36					
28		*Cananga Orodata*	27,38	8,72					
29		*Cananga Orodata*	23,56	7,5					
30		*Pterocymbiumjavanicum*	18,63	5,93					
31		*Kleinhovia hospital* L.	18,78	5,98					
32		*Diospyros celebica*	23,88	7,61					

Source :Primary Data , 2024

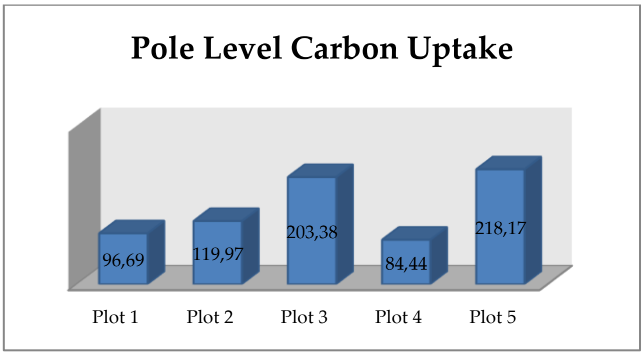

Figure 4. Graph of CO2 uptake at Pole Level in each plot

Based on the calculation results for total biomass and total carbon content at the pole level, the one with the highest carbon uptake value is in plot 5 in total with a total biomass of 119 kg/tree, which has a total of 8 individuals with a carbon uptake of 218.17 kg/tree. With a total carbon uptake on the pole of 722.65 tonnes/ha.

3.1. Stake Level Carbon Uptake Potential

Table 3. Total biomass and carbon uptake at sapling level

No	Plot	Kinds	K	D	BiomassaTotal (Kg/plot)	biomassa Total (25 m^2)	C (ton/ha)	Uptake CO2 (kg/pohon)	Total CO2 Sanctuary (ton)
1	1	*Horsfieldabivalvis*	7,32	2,33	3,41	34,86	1,7	6,25	63,91
2		*Planchoniavalida*	5,09	1,62					
3		*Pangiumedule*	8,28	2,64					
4		*Pometia pinnata*	6,05	1,93					
5	2	*Sterculia insularis*	8,69	2,77	8,54		4,27	15,65	
6		*Palaquiumobovatum*	5,15	1,64					
7		*Cananga Orodata*	10,66	3,39					
8		*Garuga floribunda*	5,57	1,77					
9		*Cananga Orodata*	5,63	1,79					
10		*Kleinhovia hospital* L.	9,5	3,03					
11		*Magnolia champaka*L.	6,84	2,18					
12	3	*Kleinhovia hospital* L.	10,19	3,25	7,28		3,64	13,34	
13		*Kleinhovia hospital* L.	9,23	2,94					
14		*Kleinhovia hospital* L.	10,19	3,25					
15		*Planchoniavalida*	6,05	1,93					
16	4	*Kleinhovia hospital* L.	9,71	3,09	6,27		3,14	11,5	
17		*Horsfieldabivalvis*	7,48	2,38					
18		*Kleinhovia hospital* L.	8,91	2,84					
19		*Horsfieldabivalvis*	8,28	2,64					
20	5	*Magnolia champaka*L.	6,05	1,93	9,36		4,68	17,16	
21		*Kleinhovia hospital* L.	7,96	2,54					
22		*Endospermumpeltatum*	7,64	2,43					
23		*Pimelodendronambonicum*	9,55	3,04					
24		*Pangiumedule*	10,82	3,45					
25		*Pangiumedule*	5,09	1,62					
26		*Kleinhovia hospital* L.	7,64	2,43					

Source :Primary Data, 2024

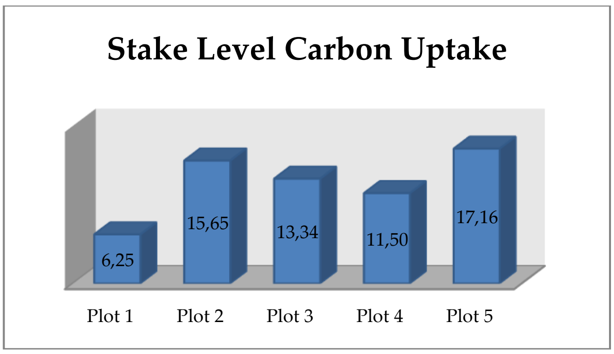

Figure 5. Graph of CO2 Absorption at Sapling Level in each plot

Based on the calculation results for total biomass and total carbon content at the sapling level, the one with the highest carbon uptake value was in plot 5 with a total biomass of 9.36 kg/tree, which had 7 individuals with carbon uptake of 17.16 kg/tree. With total carbon uptake in saplings of 63.91 tonnes/ha.

The total value of carbon uptake for each type of tree for each level of tree, pole and sapling is presented in the following table.

Table 4. Carbon Uptake in the Maleo Hungayono Sanctuary

No	Strate	Uptakecarbon (ton/ha)
1	Tree	16588,26
2	Pole	722,65
3	Stake	63,91
Total		17.374,82

Source : Primary Data, 2024

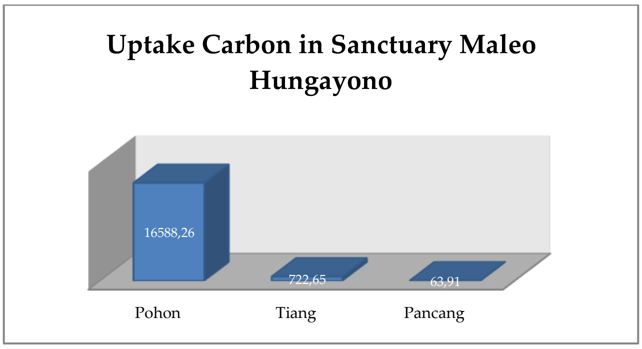

Figure 6. Uptake Carbon in Sanctuary Maleo Hungayono

The carbon content of plants describes how much the plant absorbs CO^2 from the air. Some of the carbon will become energy for plant physiological processes and some will enter the plant structure and become part of the plant, for example cellulose which is stored in stems, roots, twigs and leaves (Baderan, 2017). Based on the calculation results for the total carbon content in trees, poles and saplings which had the highest value in each observation plot, it was obtained that the highest carbon uptake value was at the tree level of 16,588.26 tonnes/ha. Furthermore, carbon uptake at the pile level was 722.65 tonnes/ha, and the lowest was at the stake level at 63.91 tonnes/ha. With a total carbon uptake from trees, poles and stakes of 17,374.82 tonnes/ha.

3.2.5. Environmental Factors of the Maleo Hungayono Sanctuary, TNBNW Area

Table 5. Environmental Factors in the Maleo Hungayono Sanctuary, TNBNW Area.

Plot	Environmental Factors			
	Degree (^0C)	Light Intensity (Cd)	Humidity (%)	Ph
1	28,2	5285	99	6
2	28,8	5897	99	6,1
3	28,6	5198	91	6
4	29,3	5239	86	6,1
5	29,1	5500	84	6

Source: Primary Data, 2024

Based on Table 9, it shows the environmental factors in the Maleo Sanctuary in the TNBNW area, namely in plot 1 the temperature is 28.2 ^{0}C, light intensity 5285 Cd, humidity 99% and pH 6. In plot 2 the temperature is 28.8 ^{0}C, light intensity 5897 Cd, humidity 99% and pH 6.1. In plot 3 the temperature is 28.6 ^{0}C, light intensity 5198 Cd, humidity 91%, and pH 6. In plot 4 the temperature is 29.3 ^{0}C, light intensity 5239 Cd, humidity 86%, and pH 6.1. In plot 5 the temperature is 29.1 ^{0}C, light intensity 5500 Cd, humidity 84%, and pH 6.

3. CONCLUSION

The types of trees found in the Maleo Hungayono Sanctuary in the TNBNW area were found to be 22 tree species, namely *Ficus variegata, Cananga orodata, Vitex copassus, Garugaflorbunda, Pangiumedule, Octomelessumantrana, Pometia pinnata, Pterocymbiumjavanicum, Arenga pinnata, Dracontomelon Dao, Koordensiodendronpinnatum, Diospyros celebica, Palaquiumobovatum, Syzygiumlitorale, Macaranga Sp., Dendrocnidemicrostigma, Endospermumpeltatum, Tricalysiasingularis, Pimelodendronambonicum, Magnolia champaka, Horsfieldiabivalvis, Streblussasper, Kleinhovia hospital L., Planchoniavalida, Sterculia insularis* which were distributed in 5 observation plots in Maleo Hungayono Sanctuary. The total carbon content in trees, poles and saplings which had the highest value in each observation plot was obtained by total carbon uptake from trees, poles and saplings of 17,374.82 tonnes/ha.

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