The Potency of Biomass and Carbon Stocks under Agroforestry *Dusung* Areas in Maluku Indonesia

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Abstract—**The increasing carbon emission caused by human and industrial activity has a destructive impact on earth. Agroforestry as one of model in forest management has played an essential role in carbon sequestration through vegetation growth. Information about the potency of biomass is important to evaluate carbon stock in the forest. The study was conducted to determine the potential of stored biomass and carbon stocks managed by the *Dusung* of agroforestry Toisapu Negeri Hutumuri, Sirimau Protected Forest in Ambon. The study was conducted using nondestructive method in three main plots (PU) for observing vegetation at the level of poles, trees, understorey, litter, and dead organics. Observation parameters include plant biomass stocks and carbon stocks potency. The calculations for tree and pole level biomass stocks were 50.78 kg /m2, the understory was 0.26 kg/m2, litter 4.343 was kg / m2, and dead organics was 4.41 kg/m2. Assuming the amount of carbon uptake of 46%, the amount of carbon stored for trees and poles is 233.58 tons C/ha, the understorey is 1.196 tons C/ha, litter is 19.977 tons C/ha, dead organics are 20.286 tons C/ha, and soil has 0.044 tons/ha. The total value of carbon stocks stored above the soil surface in the agroforestry *Dusung* system in Ambon is 275. 092 tons C/ha and its good contribution on mitigation of climate change.**

Keywords—**Biomass; carbon stock; agroforestry; carbon sequestration.**

I. INTRODUCTION

Agroforestry is alternative land management by arranging the composition and structure of stands to increase productivity and efficiency of land use. It combine woody plant as the domain forest vegetation with crops or livestock in the same area [1], [2]. Planting several types of trees in an area can increase the economic value of the land because there are different crop rotations from the trees planted. Besides, agroforestry systems also have the function of maintaining biodiversity, food providers for both humans and livestock, wood and non-timber products and can also be a protection from wind damage. In the management of community forests, agroforestry patterns are widely applied to optimize land use. Agroforestry patterns can maximize the use of sunlight, water and nutrients so that both ecologically and economically provide more benefits when compared to monoculture planting patterns. Through the canopy strata and rooting strata, agroforestry has a useful ability in the utilization of land resources.

The role of agroforestry in carbon sequestration and biomass production is no doubt. The diverse of vegetation in agroforestry system increase carbon sequestration and biomass. About carbon stocks, agroforestry systems take carbon dioxide (CO_2) from the air through the process of plant photosynthesis and convert it to carbon stored in vegetation, dead organic matter and carbon stocks in the soil for safe storage through storage above ground and below ground level [3]. This agroforestry system has received great attention in developing countries and is believed to have greater potential compared to annual and seasonal crops [4]–[7].

In Indonesia, agroforestry has been practiced in many place with vary area, even agroforestry has important role in food security [8]. In Maluku province, there is the value of local wisdom in managing a garden called *Dusung* which is an agroforestry pattern by planting a variety of trees for generations on the same land so that the area changes to resemble community forest. The diversity of plant species in *Dusung* is thought to have considerable ability in carbon sequestration in the air. Research on carbon stocks in

the *Dusung* agroforestry system has been carried out, among others, in the Hutumury Village of Ambon City with the *Myristica fragrans* agroforestry pattern [9] and carbon storage in several types of soil in East Halmahera [10].

In the Sirimau Protected Forest area, there is a *Dusung* where the diversity of plant species in this area is thought to have considerable ability in carbon sequestration in the air. Information about the potential of biomass and carbon in *Dusung* agroforestry in this location was not well known, so this study aimed to analyse vegetation, determine the potential of biomass and carbon stored in the area.

II. MATERIALS AND METHODS

The study was conducted in the agroforestry area of the *Dusung* Protected Forest in Ambon, Maluku, which is geographically located at 03º 40 '06.7 "South and 128º 17' 36.8" East with a altitude of 50-100 meters above sea level. Further research was carried out in the Laboratory of Forest Product Technology, Faculty of Agriculture, Pattimura University, Ambon, in June - October 2018. Primary data collection is done through direct observation and measurement of field and laboratory research objects. Equipment used included Phiband, Roll meters, cameras, raffia, machetes, wind meters, GPS Garmin, Chainsaw, Hand saws, Tarps, Plastics and Sacks, Scales 50-100 Kg, Scales (digital and manual), Drying ovens, Thermometer and Computer and stationery. Vegetation sampling techniques can be seen in Table I and II. Vegetation sampling was carried out by survey method at the level of weaning, poles, and trees with a sampling intensity of 100%. Calculations using allometric equations with diameter parameters at breast height taken on all observation lines measuring 20 × 20 m² and 10 × 10 m² for measuring height and diameter of tree stand; 5 × 5 m² and 2 × 2 m² plots, for measurement of understorey.

TABLE I
MATERIAL USED IN OBSERVATION

Material observation	
A. Organic Living Material	
a. Pole and Tree Level Vegetation, referring to SNI 7724: 2011	Pole: height :> 300 cm Diameter at dbh : 10-20 cm Tree: Diameter at dbh : >20 cm
b. Seedling and sapling level vegetation, referring to SNI 7724: 2011	Seedling: since germination up to high 150 cm Sapling: height 150-300 cm, with a diameter at dbh <10 cm
B. Dead Organic Material	
Litter, referring to SNI 7724: 2011	Leaves, bark, twig fallen to the ground

TABLE II
METHOD OBSERVATION FOR VEGETATION STRUCTURE AND BIOMASS POTENCY MEASUREMENT

Observation Methods	
Category	**Methods**
A. Organic Living Material	
a. Pole and Tree Level Vegetation, referring to SNI 7724: 2011	• Vegetation survey of weaning rates, pole and tree intensity 100% (biomass calculations using equations • allometric with a diameter at breast height) • Taken on all 20 × 20 m² observation paths
b. Seedling and sapling level vegetation, referring to SNI 7724: 2011	• Taking a 300-gram ring sample of grass (calculation of the ratio of dry weight to wet weight is appropriate • the results of the furnace/oven dry • The sample ring was taken on a 2 × 2 m² measuring plot for seedling: 5 × 5 m² for a sapling, and stakes in plots measuring 20 × 20 m²
B. Dead Organic Material	
a. Litter, referring to SNI 7724: 2011	• Taking 300 grams of litter sample ring (calculation of the ratio of dry weight to wet weight is appropriate the results of the furnace/oven dry • Taken a sample ring for litter size 2 × 2 m².
b. Deadwood, referring to SNI 7724: 2011	• Estimating the volume of dead wood which collapsed and was found at the study site. • Taken if deadwood was found

Estimation of biomass values in agroforestry systems used allometric equations developed by [11] with the formula namely:

$$W = 0{,}11 \, \rho \, D^{\,2{,}62} \qquad (1)$$

Where:
W = biomass (kg/tree)
P = tree specific gravity (kg / cm³)
D = diameter at breast height (1.3 m)
and was developed by previous study [12] viz :

$$(AGB) \, Test = 0.112(\pi*D^2H)0.916 \qquad (2)$$

Where AGB is the amount of aboveground biomass, D is the diameter (m), and H is tree height (m). The following equation calculated biomass per hectare:

$$w = \sum\nolimits_{(i=1)}^{n} Wpi/A \; x \; 10000 \qquad (3)$$

Where:
W = Total biomassa (ton/ha)
Wpi = Tree biomass (ton)
A = Plot area (m²)
n = Number of trees

While belowground biomass was calculated using formula [13]:

$$BGB = 0.26 \times ABG \qquad (4)$$

Determination of the value of carbon potential in agroforestry areas based on the results of the stand inventory will be processed and calculated to estimate the amount of aboveground biomass, which is calculated the estimated amount of carbon in the agroforestry system with the formula [14].

$$C = 0.5 \; x \; Y \qquad (5)$$

where:
C = amount of carbon and Y = amount of biomass.

Determination of the number of stored carbon stocks for the entire plot using the formula.

$$C_{plot} = (C_{bap} + C_{litter} + C_{km} + C_{pm} + C_{soil}) \qquad (6)$$

where:

C_{plot}	=	The total carbon stocks in the plot (ton/ha).
C_{bap}	=	The total surface biomass stocks per hectare in the plot (ton/ha)
C_{litter}	=	The total litter biomass carbon stocks per hectare in the plot
C_{km}	=	The total carbon stocks of deadwood per hectare in the plot (ton/ha)
C_{pm}	=	The total carbon stocks of dead trees per hectare in the plot (ton/ha)
C_{soil}	=	Total soil carbon stocks per hectare in the plot (ton/ha)

III. RESULTS AND DISCUSSION

A. Estimation of Tree Biomass

Estimating the value of tree biomass in this study used an indirect method by using the allometric equation that previous researchers have developed. Estimation of biomass has been done by measuring height, diameter at breast height (dbh), and a basic tree density. Determination of measuring plots based on the distribution of plant species in community forests in the Toisapu hamlet, Negeri Hutumuri considers biomass measurements based on plant height and diameter. The value of the measurement of plant biomass based on the tree's height and diameter for each plot is presented in Tables III, IV and V where the biomass was calculated [11]. $W = 0.11 \rho D^{2.62}$. Basic density of *Durio zibethinus* is 0.64, *Lansium sp* is 0.56, and *Myristica fragrans* is 0.5.

TABLE III
TREE BIOMASS MEASUREMENT RESULTS STORED IN PLOT 1

Types of Trees	Ø (Cm)	Claer Bole (M)	Height (M)	V (m³)	Biomass (g)
Tree level					
Area of Sample Plots 20 x 20 m²					
Durio zibethinus	70	17	29.5	4.55	4805.40
Myristica fragrans	24	3	23.5	0.09	227.25
Myristica fragrans	25	2.1	22	0.07	252.91
Durio zibethinus	46	20	27	2.31	1,599.55
Myristica fragrans	25	6.5	28	0.22	252.91
Lansium domesticum	24	5	20	0.16	236.34
Myristica fragrans	33	5.5	27.5	0.33	523.44
Durio zibethinus	95	18	27.5	8.87	10695.68
Total Tree Biomass					**18593.50**
Pole Level					
Sample Plot Size 10 x 10					
Myristica fragrans		18.5	22	0.091	20.04
Total Pole Biomass					**20.04**
Total Tree and Pole Biomass					**18,613.54**

TABLE IV
TREE BIOMASS MEASUREMENT RESULTS STORED IN PLOT 2

Types of Trees	Ø (Cm)	Claer Bole (M)	Height (M)	V (m³)	Biomass (g)
Tree level					
Area of Sample Plots 20 x 20 m²					
Durio zibethinus	59	16	28.3	3.04	3,070.47
Durio zibethinus	78.5	15	34.8	5.05	6,488.30
Durio zibethinus	45	10	38.3	1.11	1,510.04
Durio zibethinus	60	9	11.2	1.77	3,208.70
Durio zibethinus	52	22.5	38.5	3.32	2,205.47
Durio zibethinus	60	10	36.5	1.97	3,208.70
Durio zibethinus	43	18.5	36.9	1.87	1,340.48
Durio zibethinus	67	15	30.4	3.68	4,284.39
Durio zibethinus	42.5	19	28.5	1.87	1,300.02
Lansium sp	23	8	12.2	0.23	227.67
Lansium sp	25	5	15	0.17	283.26
Myristica fragrans	26	3	15.9	0.11	280.28
Durio zibethinus	56	16	22.5	2.74	2,678.09
Total Tree Biomass					**30,085.88**
Pole Level					
Sample Plot Size 10 x 10 m²					
Durio zibethinus	13	8	10	0.07	58.36
Lansium domesticum Lansium domesticum	17	7	14	0.11	95.76
Lansium domesticum	12.5	6.5	10.5	0.05	42.79
Lansium domesticum Lansium domesticum	15	8	12	0.10	68.99
Lansium domesticum	14.5	11	14.5	0.13	63.12
Total Pole Biomass	**709**			**27.384**	**329.01**
Total Tree and Pole Biomass					**30,414.89**

TABLE V
RESULTS OF CALCULATION OF TREE BIOMASS STORED IN PLOT 3

Types of Trees	Ø (Cm)	Claer Bole (M)	Height (M)	V (m³)	Biomass (g)
Tree level					
Area of Sample Plots 20 x 20 m²					
Lansium sp	27	5.5	16	0.22	346.54
Syzygium aromaticum	23.5	7.5	15.5	0.23	516.15
Lansium sp	21	3.5	17	0.08	179.39
Lansium sp	25.5	5	12	0.18	298.34
Durio zibethinus	29.5	9	16	0.43	136.89
Durio zibethinus	23.5	10.5	15.5	0.32	70.86
Total Tree Biomass					**1,548.17**
Pole Level					
Sample Plot Size 10 x 10 m²					
Lansium sp	13.5	4	9.5	0.04	56.37
Lansium sp	19	5.5	9	0.11	138.01
Myristica fragrans	12	7	8.5	0.05	12.78
Total Biomass Pole	**194.5**			**1.65**	**207.16**
Total Tree and Pole Biomass					**1,755.33**

The data of plot 1 - plot 3 show that the highest stored biomass is dominated by *Durio zibethinus*, *Myristica fragrans,* and *Lansium domesticum*. Compared to biomass among plots, plot 2 has the highest value because it is dominated by *Durio zibethinus* trees, while other plots are dominated by *Lansium domesticum* and *Lansium sp*.

B. Carbon Measurement from the Poles and Trees Vegetation Biomass

The amount of biomass and carbon for pole and tree classes in 3 test plots can be seen in Table VI.

TABLE VI
CARBON STOCKS, STANDS AND TREE BIOMASS

Plot	Stands Trees and Poles	∑ Volume (m³)	∑ Biomass (gr)	Total C (gr)
I	*Myristica fragrans, Durio zibethinus, Lansium domesticum.*	16.70	18,613.54	8,562.22
II	*Durio zibethinus, Lansium sp Myristica fragrans, Lansium domesticum*	27.38	30,414.89	13,990.84
III	*Lansium sp, Syzygium aromaticum, Durio zibethinus , Lansium domesticum, Myristica fragrans*	1.65	1,755.34	807.45
		45.73	50,783.77	
	Amount of Carbon ton C/ha		**233.6**	

The measurement of diameter and height, vegetation structure of pole and tree level in Table VI above show that the total volume of trees calculated is different from the amount of biomass produced. This can be seen from the biomass content stored in vegetation types based on diameter and plant height. This condition shows that the larger the stem of a plant, the higher the value of the plant biomass. Likewise, the magnitude of carbon and tree biomass content varies based on the plant being measured, growth stage, plant level, and environmental conditions.

C. Measurements of Carbon from Understory Biomass

Canopy density or plant stand is a factor that influences forest plants growth due to competition for sunlight. The understory utilizes sunlight that can penetrate the forest floor through gaps between the dominant tree canopies. The characteristics of understory formations in a forest ecosystem are strongly influenced by the ability to live and survive. When harvesting destructively, the type of understory found varies from species ranging from vines such as grasses to those that grow sporadically based on growth factors (site) or tillers from parent plants that grow under the auspices of the host. The results of the amount of understory biomass in the three plots, which were destructively sampled after weighing and calculating dry weight, are presented in Table VII.

TABLE VII
CARBON STOCKS OF UNDERSTORY BIOMASS

Measurement Plot	Understory	Biomass Value		Organic C Value
		g	Kg	Kg
I	30	30	0.03	0.014
II	140	140	0.14	0.064
III	90	90	0.09	0.041
		Amount =	0.261	0.120

The amount of biomass produced by understories such as bushes, vines, and herbs can vary, but in most forests, the percentage is about 3% of the total aboveground biomass. The carbon content and biomass of understorey are influenced by the types of constituent plants, climate, time land use and previous land use [15]

D. Carbon Measurement from Dead Organic Materials (Litter and Dead Wood).

Litter is one component in the forest that can also store carbon. The results of two carbon sources of dead organic matter, namely litter and dead wood, in the three-carbon measurement plots are presented in Table VIII.

Measure plot	Litter Type Smooth	Biomass Value Rough	Organic C Value (g)	Litter Type (Kg)	Biomass Value (Kg)
I	19	871	890	0.89	0.41
II	21	1493	1514	1.51	0.69
III	29	1910	1939	1.93	0.89
Amount				4.34	1.997

The total amount of fine and coarse litter biomass from the measurement results has different values from the three plots measured. The smallest litter biomass measurement results in measurement plots 1, while the most significant value in measurement plots 3. The results of the measurement amount in the measuring area of 2 × 2 m² or a total area of 12 m² the total amount of litter biomass is 4.34 kg with the potential amount of stored carbon stocks amounting to 1.99 kg / m² or 19.97 tons/ha. The results of measurements of deadwood litter (necromass) in the three measurement plots with different values for plot 1 with the lowest value of 0.291 kg, followed by plot 2 of 0.94 kg and plot 3 of 3.18 kg. The results of the measurement of the amount of biomass for the 20 × 20 m² plot size of the three demonstration plots covering an area of 1200 m² or 0.12 ha have total deadwood biomass of 4.41 kg with the potential amount of stored carbon stocks of 20.860 kg/m² or 20.86 tons/Ha.

Based on the calculation of the biomass value to the number of carbon stocks in the three plots, it shows that the potential of biomass is 50.78 kg/m² (507800 kg/ha). Assuming the amount of carbon sequestration is 46% [16] the total carbon stocks stored in the three tree plots and poles is 233.6 tons C/ha. Meanwhile, the measurement of carbon storage in the agroforestry system in Kampar District, North Sumatera with the dominance of rubber, *Durio zibethinus* and agarwood trees has a carbon stock value of 62.26 C ton/ha [17]. In other agroforestry system in West Java on degraded land, the potential carbon stock showed amount 108.8 Mg ha⁻¹ in a variety and density of trees [18]

The calculation results in the Table XI show that there are significant differences in the amount of understorey biomass measured from the three 2 × 2 m² plots. This different biomass value will directly describe the existence of the amount and value of carbon obtained for each plot.

The measurement results show that measurement plots 1 has the lowest value of understorey biomass, while measurement plots 3 shows the highest biomass. According to [14]), the amount of biomass produced by understorey such as bushes, vines, and herbs can vary, but generally, in most forests, the percentage is about 3% of the total biomass above the surface.

The results of this study indicate that the understorey carbon potential is 1.196 C tons/ha. This result is much higher when compared to the carbon potential of the understorey in the agroforestry system in the Kampar sub-district at 0.77 C tons/ha [19]. Meanwhile, the potential of understorey carbon in the forest stands in Mount Halimun National Park, Salak is not much different from the results of this study which amounted to 1.97 tons C/ha [20]. This difference can be caused by the type and density of understorey and land

management models. Furthermore, stated that the types of constituent plants influence the carbon stocks and biomass of understorey.

E. Carbon Measurement in Topsoil

Agroforestry practiced influence on soil organic carbon sequestration primarily the previous type of land use. The carbon element in the soil exists in 4 forms, namely carbonate minerals, solid elements such as charcoal, graphite and coal, the form of humus as the remains of plants and animals and micro-organisms that have undergone changes, but is relatively resistant to weathering and the latter as plant and animal remains that have undergone decomposition in the soil. Soil organic carbon determination based on estimated carbon content refers to soil analysis results for the three measurement demonstration plots presented in Table IX.

Soil sample	Wet weight Sample (g)	Dry weight Sample (g)	Weight (kg)	C Organic content (Ton/ha)
Sample 1	1189.27	937.53	1.065	0.0027
Sample 2	1118.17	765.26	0.820	0.0021
Sample 3	1463.78	1182.01	1.654	0,0041
Soil Volume	3771.22	2884.8	3.539	0.0088
		Carbon content Kg/m² =		0.004423
		Carbon content Ton/ha =		0.04423

The measurement of the amount of organic C content for the area of the 20 × 20 m² sample plot was taken with a representative ring sample from the three plots with an area of 1200 m² or 0.12 ha. The value of the soil volume sample's result based on the representative ring sample of 3.359 Kg/m² which multiplied by the assumption of 0.5%, made the soil organic C value is 0.0044 Kg/m² or 0.044 ton/ha. The laboratory analysis of soil samples to determine the value of the decomposition C/N ratio are presented in Table X.

Sample	Texture			Class Texture	C/N
	Sand	Silt	Clay		
Plot 1	45	28	27	Loamy clay	14
Plot 1	51	14	34	Sandy loamy clay	19
Plot 2	36	32	32	Loamy clay	14
Plot 2	28	45	27	Loamy clay	14
Plot 3	36	32	32	Loamy clay	10
Plot 3	45	28	27	Loamy clay	15
			Mean		14.33

The C/N ratio is the ratio of of the mass of carbon to the mass of nitrogen in a substance. Table 10 shows that mean of C/N ratio is 14.33. In organic material which still new, it has a higher C/N ratio than the C/N ratio after the composting process. The duration to decompose organic matter depends on several factors, one of which is the type of organic material itself. The role of decomposing microorganisms related to their larger population will help to accelerate the process of decomposition and weathering.

Carbon is a component of organic matter, therefore its circulation during the weathering of plant tissues is very important. Most of the energy required by the soil flora and

fauna get from carbon oxidation, therefore CO_2 continues to be formed. The release of CO_2, among others, is through the weathering mechanism of organic matter. This gas is a source of soil CO_2, in addition to CO_2 released by plant roots and carried by rainwater. The CO_2 produced by the soil will eventually be released into the air, then used again by plants.

F. Estimation of Carbon Content from the Absorption and Absorbance Process of Understory Biomass

The components of terrestrial carbon stocks consist of aboveground carbon stocks, belowground carbon stocks, and other carbon stocks. One factor that can reduce the accumulation of carbon dioxide (CO_2) in the atmosphere is absorption by vegetation. The analysis of carbon content in the laboratory from the absorption and absorbance processes of understory biomass samples is presented in Table XI.

TABLE XI
C/N RATIO OF SOIL SAMPLE IN MEASUREMENT PLOT

Sample	Weight (gr)	Area	Concentration (ppm)	Carbon content (%)	Carbon content weight (gr)
Plot I	0.0252	0.24	90.3	17.9	0.005
Plot II	0.0252	0.251	95.8	19.0	0.005
Plot III	0.0252	0.23	85.3	16.8	0,004
			Carbon (kg/m²)		0.0000135

According to Table XI, it showed that the ability to absorb carbon is very different and depends on internal plant factors, which indicate the amount of carbon content resulting from the photosynthesis process and its distribution to all plant tissue. There is a strong correlation between carbon concentration with absorption and absorbance.

G. Estimation of Carbon Content from Absorption and Absorbance of Litter

The litter layer of the forest floor is all dead organic material that is above the soil surface. The amount of carbon and tree biomass and litter varies according to the plant's part being measured, growth stage, plant level, and conditions of the decomposition/weathering process and the environment. The analysis of carbon content in the laboratory from the absorption and absorbance processes of course and fine litter samples is presented in Table XII.

TABLE XII
ABSORBANCE CARBON IN LITTER

Sample	Weight (gr)	Area	Concentration (ppm)	Carbon content (%)	Carbon content weight (gr)
Fine litter 1	0.025	0.22	81.3	16.18	0.004065
Fine litter 2	0.025	0.23	86.3	17.19	0.004315
Fine litter 3	0.025	0.21	78.3	15.47	0.003915
Coarse litter 1	0.025	0.20	70.8	13.937	0.00354
Coarse litter 2	0.025	0.248	94.3	18.7103	0.004715
Coarse litter 3	0.025	0.265	102.8	20.4781	0.00514
			Carbon (kg/m²)		0.0000256

Table XII showed that the ability to absorb carbon is determined by the process of litter decomposition and will be different depending on climatic factors and the activity of soil organic matter that supposed the weathering process. The flow of carbon from the atmosphere to vegetation is a two-way flow, namely the binding of CO_2 into the biomass through photosynthesis and the release of CO_2 into the atmosphere through decomposition and combustion [21].

Part of the amount of C absorbed from the free air is transported to the roots as carbohydrates. Litter and dead roots that enter the soil will be immediately destroyed by heterotrophic biota and enter the soil organic matter pool. While the loss of C from the soil can be through (a) soil respiration, (b) plant respiration, (c) transported by harvest, (d) used by biota, (e) erosion [21]

H. Estimation of aboveground carbon content from measurements of three carbon measurement plots

Stored carbon in a forest community is strongly influenced by plant diameter and density. Trees, as the main constituent of forests, need sunlight, carbon dioxide (CO_2), which is absorbed from the air, and nutrients and water absorbed from the soil for their survival. A forest community system consisting of tree species with high wood density values will have higher biomass when compared to forest communities that have tree species with low wood density values [21]. Estimation of the total carbon content in Toisapu Negeri Hutumuri Hamlet is presented in Table XIII.

TABLE XIII
CARBON CONTENT IN 3 MEASUREMENT PLOT

Material	Biomass (kg/ha)	Carbon (ton/ha)
Vegetation (trees, poles, saplings, seedling)	507800	233.6
Understory	2600	1.196
Deadwood	44100	20.286
Litter	43430	19.977
Soil		0.0442
	Total	275.092

Estimating the total stored carbon content in the community forest of Toisapu Negeri Hutumuri was calculated from biomass measurements for each parameter. The estimated stored carbon for tree and pole stands were calculated using allometric equations, estimation of understory (sapling and cover crop), fine and coarse litter (necromass), soil c organic content using the sample dry weight method. The results of the measurement of total biomass from each parameter are calculated to estimate the total carbon content (C value) stored above the soil surface for the use of agroforestry land using the *Dusung* system in 2018 measurements in Toisapu Negeri Hutumuri Hamlet of 275.092 tons/ha.

Table XIII showed that the highest biomass and carbon are stored in vegetation (84,9%). The biomass stocks stored in vegetation measurement based on diameter and plant height. Biomass was calculated by the formula of [11], where the parameters used are the diameter and basic density of the tree. This condition shows that the higher the diameter of the trunk of a plant, the higher the plant's biomass value. According to [22] states that the amount of carbon stock between land varies, depending on the diversity and density of existing plants, soil types and how to process them. Furthermore, stated that the amount of carbon stocks and tree biomass is strongly influenced by tree size, tree age, growth rate, and environmental conditions such as temperature and rainfall.

Above-ground biomass (AGB) in Toisapu Negeri Hutumuri was estimated at 507800 kg/ha (507.8 ton/ha). At the same time, belowground biomass was 132028 kg/ha (132.0 ton/ha). Generally, AGB greater than BGB due to trees' growth mainly occurs above ground due to physiologis metabolisme need sunlight and coarbondiaoxide where this componen more available in the above ground. Biomass in above ground is stored in stem, trunk, and leaves, while in belowground only stored in the root.

Lowland forests store most of the land's carbon stocks because forest vegetation absorbs carbon dioxide through photosynthesis activity and can store around 76 - 78% of organic carbon from total land organic carbon in the form of biomass [23].The amount of carbon and biomass of a tree varies based on the part of the plant being measured, growth stage, plant level, the age of trees, management system and environmental conditions [24].

Dusung of agroforestry system in Ambon is a good forest management model due to it has been carried out from generation to generation from their ancestors with various types of trees that make up the forest. The presence of canopy strata provides benefits in the utilization of sunlight and space for growth so that carbon absorption can be optimal. In addition, this model also contributes to mitigating the effects of climate change. This result supports the researchers' statement that agroecosystems play a central role in the global C cycle and contain approximately 12% of the world terrestrial C [25], [26].

IV. CONCLUSION

Dusung as a model agroforestry in Ambon has an important role in carbon sequestration and the culture should be preserved. The potential of biomass and carbon stored in the Toisapu hamlet, which is part of the Sirimau Protection Forest, is relatively large at 275.092 tons/ha, with the most carbon stored on tree poles. It is indicate that in future the ability of this area for carbon sequestration is great a long with the growth of vegetation. Protection and maintenance the Dusung of Toisapu need to be done by local government and people around the area. Enrichment planting with a various fruiyt vegetation can be applied in the area for increasing the vegetation diversity, rising canopy level and improving non forest timber product. The strategy to manage the protected forest area needs to be maintained for supporting vital role in climate change mitigation in the city of Ambon.

REFERENCES

[1] M. R. Mosquera-Losada *et al.*, "Agroforestry in Europe: A land management policy tool to combat climate change," *Land use policy*, vol. 78, no. March, pp. 603–613, 2018, doi: 10.1016/j.landusepol.2018.06.052.

[2] P. K. R. Nair, A. M. Gordon, and M. Rosa Mosquera-Losada, "Agroforestry," in *Encyclopedia of Ecology, Five-Volume Set*, 2008.

[3] P. K. R. Nair, "Carbon sequestration studies in agroforestry systems: A reality-check," *Agrofor. Syst.*, 2012, doi: 10.1007/s10457-011-9434-z.

[4] F. Montagnini and P. K. R. Nair, "Carbon sequestration: An underexploited environmental benefit of agroforestry systems," *Agrofor. Syst.*, vol. 61–62, no. 1–3, pp. 281–295, 2004, doi: 10.1023/B:AGFO.0000029005.92691.79.

[5] K. R. Kirby and C. Potvin, "Variation in carbon storage among tree species: Implications for the management of a small-scale carbon sink project," *For. Ecol. Manage.*, 2007, doi: 10.1016/j.foreco.2007.03.072.

[6] F. Abbas *et al.*, "Agroforestry: a sustainable environmental practice for carbon sequestration under the climate change scenarios—a review," *Environ. Sci. Pollut. Res.*, 2017, doi: 10.1007/s11356-017-8687-0.

[7] E. K. Anderson and H. Zerriffi, "Seeing the trees for the carbon: Agroforestry for development and carbon mitigation," *Clim. Change*, 2012, doi: 10.1007/s10584-012-0456-y.

[8] C. Duffy *et al.*, "Agroforestry contributions to smallholder farmer food security in Indonesia," *Agrofor. Syst.*, vol. 95, no. 6, pp. 1109–1124, 2021, doi: 10.1007/s10457-021-00632-8.

[9] G. Mardiatmoko, A. Kastanya, and J. W. Hatulesila, "Allometric equation for estimating aboveground biomass of nutmeg (Myristica fragrans Houtt) to support REDD+," *Agrofor. Syst.*, 2019, doi: 10.1007/s10457-018-0245-3.

[10] E. Khudzaeva, "Sebaran Stok Karbon Berdasarkan Karaktristik Jenis Tanah (Studi Kasus : Area Hutan Halmahera Timur, Kab Maluku Utara)," *Stud. Inform. J. Sist. Inf.*, 2012, doi: 10.15408/sijsi.v5i1.278.

[11] Q. M. Ketterings, R. Coe, M. Van Noordwijk, Y. Ambagau', and C. A. Palm, "Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests," *For. Ecol. Manage.*, vol. 146, no. 1–3, pp. 199–209, 2001, doi: 10.1016/S0378-1127(00)00460-6.

[12] J. Chave *et al.*, "Tree allometry and improved estimation of carbon stocks and balance in tropical forests," *Oecologia*, 2005, doi: 10.1007/s00442-005-0100-x.

[13] M. A. Cairns, S. Brown, E. H. Helmer, and G. A. Baumgardner, "Root biomass allocation in the world's upland forests," *Oecologia*, vol. 111, no. 1, pp. 1–11, 1997, doi: 10.1007/s004420050201.

[14] Brown S., "Estimating biomass and biomass change of tropical forests," *a Prim.*, 1997.

[15] D. Feliciano, A. Ledo, J. Hillier, and D. R. Nayak, "Which agroforestry options give the greatest soil and above ground carbon benefits in different world regions?," *Agric. Ecosyst. Environ.*, vol. 254, no. July 2017, pp. 117–129, 2018, doi: 10.1016/j.agee.2017.11.032.

[16] Anonim, *Standar Nasional Indonesia No. 7724. Pengukuran dan Penghitungan Cadangan Karbon –Pengukuran Lapangan untuk Penaksiran Cadangan Karbon Hutan. Badan Standarisasi Nasional. Jakarta.* Jakarta: Badan Standarisasi Nasional, 2011.

[17] E. Insusanty, M. Ikhwan, and E. Sadjati, "Kontribusi agroforestri dalam mitigasi gas rumah kaca melalui penyerapan karbon Contribution Of Agroforestry Mitigation Greenhouse Gases Through The Carbon Sequestration," *J. Hutan Trop.*, 2018, doi: 10.20527/jht.v5i3.4784.

[18] M. Siarudin *et al.*, "Carbon sequestration potential of agroforestry systems in degraded landscapes in west Java, Indonesia," *Forests*, vol. 12, no. 6, 2021, doi: 10.3390/f12060714.

[19] E. Insusanty, N. Sulistiono, and A. Azwin, "Survei potensi gaharu dengan sistem agroforestri di kecamatan xiii Koto Kampar, Kabupaten Kampar (Studi kasus: desa Pulau Gadang dan desa Koto Masjid)," *Wahana For. J. Kehutan.*, 2018, doi: 10.31849/forestra.v13i1.1280.

[20] V. B. Arifanti, I. W. S. Dharmawan, and D. Wicaksono, "Carbon Stock Potency of Sub Montane Forest Stand in Mount Halimun Salak National Park," *For. Socio Econ. Res. J.*, vol. 11, no. 493, pp. 13–31, 2014.

[21] Kurniatun Hairiah, Subekti Rahayu, *Pengukuran "Karbon tersimpan" Di Berbagai Macam Penggunaan Lahan*. Berlin: World Agroforestry Centre, ICRAF Southeast Asia, 2007.

[22] R. S. Hairiah K, Ekadinata A, Sari RR, *Pengukuran cadangan karbon dari tingkat lahan ke bentang alam*. 2011.

[23] N. E. Istomo, Farida, "Potensi Simpan Karbon di atas Permukaan Tanah Tegakan Acacia nilotica L . (Willd) ex . Del . di taman nasional Baluran Jawa Timur Above ground carbon storage potential of stand of Acacia nilotica L . (Willd) ex . Del. in Baluran National Park, East Java," *J. Pengelolaan Sumberd. Alam dan Lingkung.*, vol. 7, no. 2, pp. 155–162, 2017, doi: 10.19081/jpsl.2017.7.2.155.

[24] K. Yang and D. Guan, "Changes in forest biomass carbon stock in the Pearl River Delta between 1989 and 2003," *J. Environ. Sci.*, 2008, doi: 10.1016/S1001-0742(08)62546-2.

[25] Smith TM, Cramer WP, Dixon RK, Leemasn R, Neilson RP, Solomon AM, "The global terrestrial carbon cycle," *Clim. Chang.*, vol. 70, no. 1–4, pp. 19–37, 1993, doi: 10.1007/BF01104986.

[26] P Dixon RK; Winjum JK; Andrasko KJ; Lee JJ; Schroeder PE, "Integrated land-use systems: assessment of promising agroforest and alternative land-use practices to enhance carbon conservation and sequestration.," *Clim. Change*, vol. 27, pp. 71–92, 1994.