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Relationship Between Soil Density And Soil Organic Carbon Stock In Tembawang Agroforestry Area Of Semayang Village Sanggau Regency

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ABSTRACT

Tembawang agroforestry is composed of tree vegetation that stores abundant carbon reserves both on the surface and in the soil. Soil organic carbon plays a role in increasing soil fertility so that plant productivity and the sustainability of plant life can increase. The purpose of this study was to determine organic carbon content, and organic carbon reserve and their relationship in the Tembawang Agroforestry of Sanggau Regency. The research method for determining the sampling location used the purposive sampling method. Sampling was carried out at 5 points in each location. The method for determining organic carbon content used the Walkey and Black method. The data were analyzed using the SPSS 30 program. The results of this study show that the soil density is 0,6615 g/cm^3 to 0,7795 g/cm^3. The highest organic carbon content was 7.08% then decreased to 2.89%. Soil organic carbon reserves were 2311,38 ton/ha to 6735,60 ton/ha. Soil density had a week negative correlation with organic carbon content (r = -0,240 < 0,05) and a moderate positive correlation with organic carbon stocks (r = 0,546 < 0,01). Organic carbon content had a strong negative correlation with organic carbon reserves (r = -0,681 < 0,01). The Tembawang Agroforestry System has enormous carbon sequestration capacity. Making it an important ecosystem for climate change mitigation.

Keywords: *Agroforestry; Organic Carbon; Organic Carbon reserve; Soil Density*

INTRODUCTION

Global warming is an issue that is increasingly being felt by communities around the world. Rising temperatures and unpredictable weather are indicators of global warming (Wahyuni & Suranto, 2021). Global warming can be caused by forest destruction due to changes in forest land use to non-forest land such as oil palm plantations (Syah, 2017). (Afifuddin, 2006) states that there have been many changes in land use and function in Sanggau Regency, such as the conversion of forest areas into rubber and oil palm plantations. Forests damaged by land clearing, tree felling, and forest fires will reduce the forest's ability to store carbon, thereby increasing the amount of carbon dioxide (CO^2) in the air (Al-Reza et al., 2017).

Replanting degraded land is an important effort in reducing carbon dioxide (CO^2) because plants can absorb carbon (Sari et al., 2017). The remains of dead plants and litter will decompose, releasing carbon into the soil. Soil plays an important role in storing organic carbon, which is an important component in the global carbon cycle. Soil organic carbon is an important element in supporting soil fertility. Soil organic carbon plays a role in determining soil fertility levels (Hardjowigeno, 2010). Soil organic carbon increases soil fertility, thereby improving crop productivity and plant longevity (Sari et al., 2023).

The level of organic carbon is influenced by several factors, such as the vegetation growing in the area, decomposed biomass residues, mechanical disturbance of the soil, soil depth, and soil density (Schrumpf et al., 2011). According to Sipahutar et al. (2014), the deeper the soil, the lower the level of organic carbon. The level of organic carbon content is determined by soil density; the lower the soil density, the higher the soil organic carbon content. High soil density can reduce soil pore space, resulting in low organic carbon content (Sari et al., 2017).

The amount of carbon stored in the soil as organic carbon means that less carbon will be released into the atmosphere, thereby reducing global warming and climate change. This process is called soil carbon sequestration. Increasing soil organic carbon can improve soil quality, reduce climate change, and increase soil productivity as a means of reforestation in mining areas (Elbasiouny et al., 2022).

The amount of organic carbon reserves in an area is determined based on organic carbon content, soil depth, soil density, decomposed biomass residues, and vegetation growing in the area. Research on soil organic carbon content was conducted by Sari et al. (2017) in Tembawang Agroforestry, Sekadau Regency, which found 1,705.27–8,899.62 ton/ha. Another study was conducted by *Suardi* et al. (2016) in Sabah, Malaysia, with organic carbon reserves of 49.75 ton/ha on agroforestry land and 43.09 ton/ha on monoculture land.

The Tembawang Agroforestry area consists of a large amount of tree, shrub, and seasonal plant vegetation (Hutagaol, 2024). Agroforestry in Tembawang, Sanggau Regency, has tree vegetation that stores abundant carbon reserves both on the surface and in the soil. Soil functions as the largest carbon store in the carbon cycle in terrestrial ecosystems. As a storage site for organic carbon, soil plays a very important role in the long term because it is capable of absorbing large amounts of carbon compared to the carbon found in plant biomass and in the atmosphere (Tarnocai, 2009). Research on this topic is needed to determine the levels of organic carbon and organic carbon reserves in the Tembawang Agroforestry area in Sanggau Regency.

METHOD

Time and Sampling Location

The research was conducted from August 29, 2024 to December 2024 at the Tembawang Agroforestry in Sanggau Regency, West Kalimantan. Sampling was carried out in Semayang Village, Sanggau Regency, West Kalimantan. The sampling location in this study was determined using purposive sampling (Fachrul, 2006). The sampling location was determined based on several considerations or specific criteria, such as soil texture and vegetation at the sampling location. The research location is shown in **Figure 1**. Sampling was carried out in four Agrofotestri areas, namely:

a. Location I : Tembawang Tatei Ntowo
b. Location II : Tembawang Sungai Dengen
c. Location III : Tembawang Diat Seng
d. Location IV : Tembawang Ma Diman

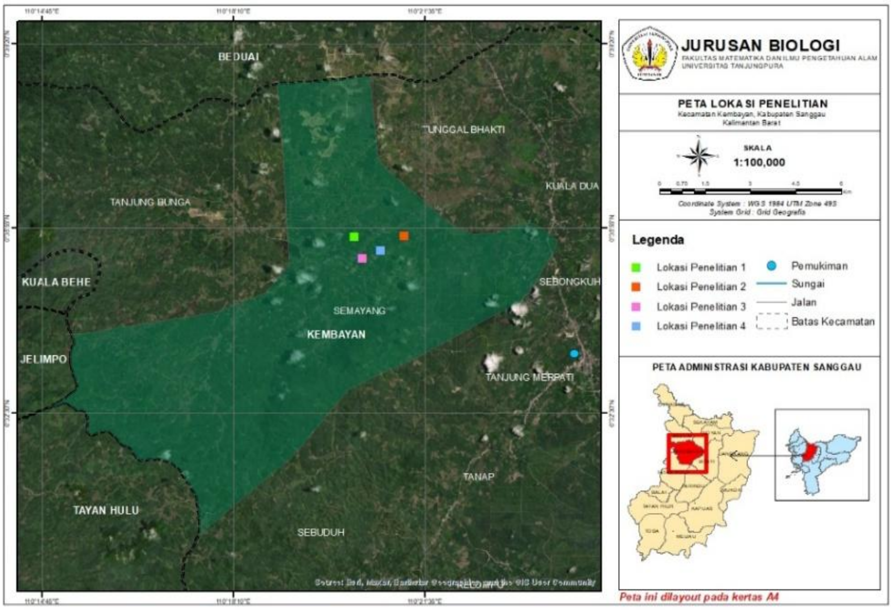

Figure 1. Research Location

Determination of Sampling Locations

Sample Collection

Sampling was conducted at four predetermined locations in the Tembawang Agroforestry area. Each location was divided into five sampling points as replicates. Soil samples were taken from 5 points, namely at the four cardinal directions and the fifth point in the middle. Sampling was carried out using a soil ring, taking samples from 5 points sequentially at each depth, with a range of 0-5 cm, 6-10 cm, 11-20 cm, and 21-30 cm at each predetermined point. Sampling was carried out sequentially according to the depth range using a 5.5 cm x 5.5 cm soil ring. The samples were then placed in plastic bags, labeled, and taken to the laboratory (SNI 7724, 2011).

Data Analysis

The data analysis used in calculating carbon biomass for soil organic matter was calculated using references from the National Standardization Agency (SNI 7724, 2011).

Soil density

The density of soil is determined by weighing samples that have been dried in an oven at a temperature of ±100°C for 24 hours and then dividing by the volume of soil. According to Hillel (1981), soil/land density can be calculated using the following formula:

$$\text{Pb (g/cm}^3) = \frac{\text{Ms}}{\text{Vt}}$$

Description:

Pb : Soil density (g/cm³)

Vt : Soil volume (cm³)

Ms : Soil mass (g)

Water content correction factor

The correction factor is determined by weighing 5.00 g of soil sample in an aluminum container with a known weight. The sample is then dried in an oven at 105°C for 3 hours. The weight of water lost is determined from the difference in weight of the sample before and after oven drying. According to (Eviati & Sulaeman, 2009), the moisture content correction factor is calculated using the following formula:

$$\text{Water content (\%)} = \frac{\text{weight of lost water}}{\text{sample weight}} \times 100$$
$$\text{Fk} = 100 / (100 - \text{\% water content})$$

FK : Water content correction factor

Organic carbon content

The organic carbon content based on the Walkey and Black method is determined using a spectrophotometer. Weigh 0.500 g of the sample and place it in a 100 ml volumetric flask. Add 5 ml of 1N $K_2Cr_2O_7$, then shake. Add 7.5 ml of concentrated H_2SO_4, shake and let stand for 30 minutes, then dilute with distilled water. Prepare standard solutions of 0, 50, 150, and 250 ppm as references. Measure the absorbance of the solution at a wavelength of 561 nm (Eviati & Sulaeman, 2009). The organic carbon content is calculated using the following formula:

$$C_{organic}\ (\%) = \text{ppm curve x (Extraction (ml) / 1000 ml) x (100 / mg sample) x fk}$$
$$= \text{ppm curve x (100 / 1000 ml) x (100 / 500) x fk}$$

Description:
ppm curve : ppm sample results from linear regression curve
ml extraction : volumetric flask volume

Carbon Stock

Carbon stock is determined by multiplying depth, density, and organic carbon content. Carbon content is calculated using the following formula (SNI 7724, 2011):

$$C_t\ (g/cm^2) = Kd \times Pb \times C_{organic}$$

Description:
C_t : soil carbon content (g/cm^2)
Kd : soil depth (cm)
Pb : soil density/compaction (g/cm^3)
$C_{organic}$: percentage of organic carbon content (%)

Organic carbon reserves per hectare are determined by multiplying the carbon content by the conversion factor. Soil organic carbon reserves per hectare are calculated using the following formula (SNI 7724, 2011):

$$C_{soil}\ (ton/ha) = C_t \times 100$$

Description:
C_{soil} : Organic carbon reserves per hectare (ton/ha)
Ct : Soil carbon content (g/cm²)
100 : Conversion factor from g/cm² to ton/ha

Statistical Test

The results obtained were analyzed using a one-way ANOVA test to examine whether there were significant differences in the mean values of the variables measured based on depth. ANOVA test results that were significantly different (p-value <0.05) were followed up with a Tukey test and Spearman's correlation test to determine the relationship between variables. Statistical analysis was performed using SPSS 30 software.

RESULTS

Soil Density in Agroforestry in Tembawang, Sanggau Regency

The results showed that the average soil density increased with depth, ranging from 0.6615 g/cm³ at a depth of 0-5 cm to 0.7795 g/cm³ at a depth of 21-30 cm (**Table 1**).

Table 1. Soil density in Tembawang Agroforestry, Sanggau Regency

soil depth (cm)	soil density (g/cm³)		ANOVA	
	N	Average	**F**	**Sig.**
0-5	20	0,6615 ± 0,21687[a]	**1,599**	**0,197**
6-10	20	0,7340 ± 0,19297[a]		
11-20	20	0,7580 ± 0,15385[a]		
21-30	20	0,7795 ± 0,15432[a]		

Based on the results of statistical analysis, it is known that there is no significant difference in soil density between depths ($F_{3,76} = 1.599$, $p > 0.05$). These results indicate that soil density at depths of 0-5, 6-10, 11-20, and 21-30 cm does not differ significantly.

Organic Carbon Content in Agroforestry in Tembawang, Sanggau Regency

The results showed that the average soil organic carbon content decreased with increasing soil depth. The highest organic carbon content was found at a depth of 0-5 cm at 7.08%, then decreased dramatically to 2.89% at a depth of 21-30 cm (**Table 2**).

Table 2. Soil organic carbon content in Tembawang Agroforestry, Sanggau Regency

soil depth (cm)	Soil organic carbon content (%)		ANOVA	
	N	Average	**F**	**Sig.**
0-5	20	7,08 ± 1,14[d]	**101,594**	**0,000**
6-10	20	5,59 ± 0,81[c]		
11-20	20	4,12 ± 0,46[b]		
21-30	20	2,89 ± 0,65[a]		

Based on the results of statistical analysis, it is known that soil organic carbon content differs significantly between depths ($F_{3,76} = 101.549$, $p < 0.05$). Further testing shows that soil organic carbon content at depths of 0-5, 6-10, 11-20, and 21-30 cm differs significantly.

Organic Carbon Stocks in Agroforestry in Tembawang, Sanggau Regency

The results showed that the average organic carbon reserves increased with depth. The lowest organic carbon reserves were found at a depth of 0-5 cm (2311.38 ton/ha) and continued to increase, reaching the highest value at a depth of 21-30 cm (6735.60 ton/ha) (**Table 3**).

Table 3. Organic Carbon Stocks in Agroforestry in Tembawang, Sanggau Regency

soil depth (cm)	Organic carbon stock(ton/ha)		ANOVA	
	N	Average	F	Sig.
0-5	20	2311,38 ± 819,526[a]	43,286	0,000
6-10	20	4039,50 ± 1036,937[b]		
11-20	20	6230,40 ± 1309,746[c]		
21-30	20	6735,60 ± 2067,833[c]		

Based on the results of statistical analysis, it is known that organic carbon reserves differ significantly between depths (F3,76 = 43.286, p < 0.05), indicating that soil depth affects the total amount of carbon stored in it. Further testing shows that soil organic carbon reserves at depths of 0-5, 6-10, and 11-20 cm differ significantly, while the 11-20 cm and 21-30 cm layers have organic carbon reserves that do not differ significantly.

Correlation Analysis

The results of the correlation analysis show that all correlations between parameters are significant (p < 0.05) (**Table 4**)

Table 4. Correlation Analysis

Parameter	N	r	sig
Pb dan C	80	-0,240*	0,032
Pb dan C_{soil}	80	0,546**	0,000
C dan C_{soil}	80	-0,681**	0,000

Description : pb : soil density, C: soil organic carbon conten, C_{soil}: soil organic carbon stocks, : soil organic carbon stocks, * : significant difference (p < 0,05), , ** : significant difference (p < 0,01),

Based on the results of the correlation analysis, it is known that soil density has a weak negative correlation with organic carbon content (r = -0.240, $p < 0.05$) and a moderate positive correlation with organic carbon reserves (r = 0.546, $p < 0.01$). Organic carbon content has a strong negative correlation with organic carbon reserves (r = -0.681, $p < 0.01$).

DISSCUSSION

Based on the results of statistical analysis (**Table 1**), it is known that there is no significant difference in soil density based on depth ($F_{3,76} = 1.599$, $p > 0.05$). These results indicate that soil density at depths of 0-5, 6-10, 11-20, and 21-30 cm does not differ significantly. Based on the results of the study (**Table 1**), the average soil density ranges from 0.6615 g/cm³ at a depth of 0-5 cm to 0.7795 g/cm³ at a depth of 21-30 cm. The results of the study show that the average soil density increases with increasing soil depth. These results are consistent with the findings of (Siringoringo, 2014) in young secondary forests, namely that soil density tends to increase with increasing soil depth. Soil density increases from 0.86 g/cm³ at a depth of 0-5 cm to 0.94 g/cm³ at a depth of 21-30 cm. According to Siringoringo

(2014), the results of soil density analysis did not differ significantly due to the low supply of organic matter from the topsoil and the slow decomposition of organic matter from roots in the lower layers. Soil density can be determined from organic carbon content data. The higher the organic carbon content in the soil, the lower the soil density.

The results of this study are also consistent with the research conducted by Sari et al. (2017) in Tembawang Agroforestry, Sekadau Regency, which states that soil density tends to increase from 0.77 g/cm³ at a depth of 0-5 cm to 0.98 g/cm³ at a depth of 21-30 cm. According to Carvalho et al. (2009), an increase in litter and roots is associated with a decrease in density in the upper soil layer. Soil with high density at a certain depth is caused by a reduction in root and litter volume in that area. According to Sugirahayu & Rusdiana, (2011), factors that affect soil density include water content, soil texture, and the size of particles in the soil. The size of these particles directly affects the bulk density of the soil.

Based on the results of statistical analysis (**Table 2**), there was a significant difference in organic carbon content based on soil depth ($F_{3,76} = 101.549$, $p < 0.05$). Further testing showed that the organic carbon content of soil at depths of 0-5, 6-10, 11-20, and 21-30 cm differed significantly. Based on the results of the study (**Table 2**), it is known that there is a decrease in value as the soil depth increases. The highest organic carbon content was found at a depth of 0-5 cm at 7.08%, then decreased dramatically to 2.89% at a depth of 21-30 cm. Based on the results (Table 2), the organic carbon content in this study was higher than that found in the study by Susanti et al. (2021) on various types of dry land use in Aceh Besar Regency, which was 1.07% at a depth of 0-5 cm and then decreased to 0.51% at a depth of 21-30 cm.

According to Sari et al. (2017), the decrease in organic carbon content in the lower layer occurred due to the accumulation of organic matter caused by high litter decomposition in the upper layer, so that the organic carbon content at a depth of 0-5 cm generally tended to be higher than at a depth of 21-30 cm. The significantly different results of the follow-up test were caused by the accumulation of soil organic matter resulting from higher litter decomposition in the upper layer and decreasing in the lower soil layer. According to Siringoringo (2014), soil organic carbon levels are more concentrated in the upper layer because most of the soil organic carbon supply comes from litter located on the surface. The supply of carbon from surface litter decreases with increasing depth, resulting in lower organic carbon content.

The results of the organic carbon reserve study (**Table 3**) show an increase in value with increasing depth. The lowest value was found at a depth of 0-5 cm (2311.38 ton/ha) and continued to increase, reaching the highest value at a depth of 21-30 cm (6735.60 ton/ha) (**Table 3**). Salimon et al. (2009) stated that the soil surface has low organic carbon reserves due to forest management activities using the clear-cut method, which causes major disturbances to the topsoil. This clear-cut method causes organic matter to become vulnerable to decomposers, thereby reducing organic carbon reserves. According to Chen et al. (2004), differences in the amount of organic carbon reserves at each depth are influenced by the amount of organic matter, chemical composition, and the rate of decomposition in roots and litter.

Based on the results of statistical analysis (**Table 3**), there was a significant difference in carbon reserves between depths ($F_{3,76}$ = 43.286, $p < 0.05$). These results indicate that soil depth affects the total amount of carbon stored in the soil. Further testing shows that organic carbon reserves at depths of 0-5, 6-10, and 11-20 cm are significantly different. These results are thought to be due to the high rate of litter decomposition. Soil at depths of 11-20 cm and 21-30 cm have organic carbon reserves that are not significantly different. This result is thought to be due to low decomposition at these depths. According to Jobbagy & Jackson (2000), the topsoil layer (0-20 cm) generally becomes an active zone for organic matter accumulation due to litter input, root exudates, and high microbial activity, so that organic carbon variation is more dynamic and susceptible to environmental changes. According to Rumpel & Kogel-Knabner (2011), the lower soil layer (20-30 cm) experiences a decrease in organic matter input and slower decomposition processes due to reduced oxygen, stable temperatures, and limited biotic activity, which causes homogenization of organic carbon reserves in that layer. *Schmidt* et al. (2011) stated that interactions between organic matter and soil mineral particles in the deeper layers can stabilize carbon and reduce variability between layers.

Based on the results of the study, it is known that the organic carbon reserves in Tembawang Agroforestry in Sanggau Regency are greater than the results of Muardimansyah et al. (2016) study on protected forests in coffee plantations in Donggala Regency, which have organic carbon reserves of 32.93 ton/ha at a depth of 0-10 cm to 17.03 ton/ha at a depth of 20-30 cm. Another study conducted by Sari et al. (2017) in Tembawang Agroforestry, Sekadau Regency, found soil carbon reserves of 8,899.62 ton/ha at a depth of 20-30 cm, which is greater than the results of this study. This comparison shows that the Tembawang Agroforestry area has higher organic carbon reserves than other forest areas. These results are influenced by the difference in vegetation between the Tembawang Agroforestry area and other forest areas. According to Suardi et al. (2016), agroforestry land has higher organic carbon reserves than organic carbon reserves in monoculture land.

The results of Spearman's correlation analysis (**Table 4**) show that soil density has a weak negative correlation with organic carbon content ($r = -0.240$, $p < 0.05$). These results indicate that soil organic carbon content tends to decrease with increasing depth, influenced by increasing soil density. Soil density has a moderate positive correlation with organic carbon reserves ($r = 0.546$, $p < 0.01$). This correlation also indicates that an increase in soil density is directly proportional to an increase in organic carbon reserves in the soil. According to Siringoringo (2014), the level of organic carbon content is influenced by soil density. Higher soil density causes a greater mass of soil to be contained, resulting in an increase in organic carbon content and reserves. According to Six et al. (2002), soils with high density can usually reduce the rate of organic matter decomposition due to limited oxygen and microbial activity. This condition allows the accumulation of organic carbon reserves over a longer period of time.

The results of Spearman's correlation analysis (**Table 4**) show that organic carbon content has a strong negative correlation with organic carbon reserves ($r = -0.681$, $p < 0.01$). This correlation indicates that an increase in organic carbon content causes low organic carbon reserves in the soil. The negative correlation is influenced by differences in soil density at each depth. The negative correlation between organic carbon content and reserves indicates that physical soil variables (soil density) have a more dominant influence in determining carbon stocks than carbon concentration itself. This is supported by Sari et al. (2017), whose research results state that organic carbon content is negatively correlated with organic carbon reserves. The decrease in organic carbon content in the lower layers is often compensated by a significant increase in bulk density, thereby increasing carbon reserves. These results are also in line with the findings of Siregar (2007), who stated that organic carbon reserves increase with depth, from 20.80 tons/ha at a depth of 0-5 cm to 96.39 tons/ha at a depth of 21-30 cm, because the soil mass is greater (more compact) than the surface layer (0-5 cm).

CONCLUSION

The Tembawang Agroforestry System has enormous carbon sequestration capacity. The highest organic carbon content reaches 7.08%, and organic carbon reserves range from 2,311.38 ton/ha to 6,735.60 ton/ha, making it an important ecosystem for climate change mitigation.

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REFERENCES

Afifuddin, Y. (2006). *Penilaian Ekonomi Agroforestri Tembawang di Kabupaten Sintang dan Sanggau Provinsi Kalimantan Barat, Tesis*. Institut Pertanian Bogor.

Al-Reza, D. D., Hermawan, & Prasetyo, L. B. (2017). Potensi Cadangan Karbon Di Atas Permukaan Tanah Di Taman Hutan Raya Pancoran Mas Depok. *Media Konservasi*, *22*(1), 71–78.

Carvalho, J. L. N., Carlos Eduardo Pelegrino, C., Feigl, B. J., Píccolo, M. D. C., Godinho, V. D. P., Herpin, U., & Cerri, C. C. (2009). Conversion of cerrado into agricultural land in the south-western Amazon: Carbon stocks and soil fertility. *Scientia Agricola Journal*, *66*(1), 233–241.

Chen, C. R., Xu, Z. H., & Mathers, N. J. (2004). Soil carbon pools in adjacent natural and plantation forests of subtropical Australia. *Soil Science Society of America Journal*, *68*(1), 282–291.

Elbasiouny, H., El-Ramady, H., Elbehiry, F., Rajput, V. D., Minkina, T., & Mandzhieva, S. (2022). Plant Nutrition under climate change and soil carbon sequestration. *Sustainability*, *14*(2).

Eviati & Sulaeman. (2009). *Analisis Kimia Tanah, Tanaman, Air, dan Pupuk, Balai Penelitian Tanah, Balai Besar Litbang Sumber Daya Lahan Pertanian*. Badan Penelitian dan Pengembangan Pertanian, Departemen Pertanian.

Fachrul, M. (2006). *Metode Sampling Bioekologi*. Bumi Aksara.

Hardjowigeno, S. (2010). *Ilmu Tanah*. Akademika Pressindo.

Hutagaol, R. R. (2024). Keanekaragaman Jenis Buah Edible Pada Agroforestri Tembawang Tapang Tanjung Sintang Kalimantan Barat. *Jurnal piper*, *20*(2), 128–136.

Jobbagy, E. G., & Jackson, R. B. (2000). The vertical distribution of soil organic carbon and its relation to climate and vegetation. *Ecological, applications.10(2*, 423–436.

Muardimansyah, S., Akhbar, A., & Arianingsih, I. (2016). Cadangan Karbon Tanah Pada Berbagai Tingkat Kerapatan Tajuk Di Hutan Lindung Kebun Kopi Desa Nupabomba Kecamatan Tanantovea Kabupaten Donggala. *Jurnal Warta Rimba*, *4*(1), 125–131.

Rumpel, C., & Kogel-Knabner, I. (2011). Deep soil organic matter a key but poorly understood component of terrestrial C cycle. *Plant and Soil*, *338*(1), 143–158.

Salimon, C. I., Wadt, P. G. S., & Souza Alves, S. (2009). Decrease in carbon stocks in an oxisol due to land use and cover change in southwestern Amazon. *Ambiente e Agua-An Interdisciplinary Journal of Applied Science*, *4*(2), 57–65.

Sari, R., maryam, & Yusmah. (2023). Penentuan C-Organik Pada Tanah Untuk Meningkatkan Produktivitas Tanaman dan Keberlanjutan Umur Tanaman Dengan Metoda Spektrofotometri Uv Vis. *Jurnal Teknologi Pertanian*, *12*(1), 11–19.

Sari, T., Rafdinal, & Linda, R. (2017). Hubungan Kerapatan Tanah, Karbon Organik Tanah dan Cadangan Karbon Organik Tanah Di Kawasan Agroforestri Tembawang Nanga Pemubuh Sekadau Hulu Kalimantan Barat. *Jurnal Protobiont*, *6*(3), 263–269.

Schmidt, M. W., Torn, M. S., Abiven, S., Dittmar, T., Guggenberger, G., Janssens, I. A., & Trumbore, S. E. (2011). Persistence of soil organic matter as an ecosystem property. *Nature*, *478*(7367), 49–56.

Schrumpf, M., Schulze, E. D., Kaiser, K., & Schumacher, J. (2011). How Accurately Can Soil Organic Carbon Stocks and Stock Changes be Quantified by Soil Inventories. *Biogeosciences*, *8*(5), 723–769.

Sipahutar, A. H., Marbun, P., & Fauzi, F. (2014). Kajian C-Organik, N dan P Humitropepts pada ketinggian tempat yang berbeda di Kecamatan Lintong Nihuta. *Jurnal Agroekoteknologi Universitas Sumatera Utara*, *2*(4), 1332–1338.

Siregar, C. A. (2007). Pendugaan biomasa pada hutan tanaman pinus (Pinus merkusii Jungh et de Vriese) dan konservasi karbon tanah di Cianten, Jawa Barat. *Jurnal Penelitian Hutan dan Konservasi Alam*, *4*(3), 251–266.

Siringoringo, H. H. (2014). Perbedaan simpanan karbon organik pada hutan tanaman Acacia Mangium Wild dan hutan sekunder muda. *Jurnal Penelitian Hutan dan Konservasi Alam*, *11*(1), 13–39.

Six, J., Conant, R. T., Paul, E. A., & Paustian, K. (2002). Stabilization mechanisms of soil organic matter: Implications for C-saturation of soils. *Journal Plant and Soil*, *241*, 155–176.

Standar Nasional Indonesia. (2011). *Pengukuran Dan Penghitungan Cadangan Karbon dan Pengukuran Lapangan Untuk Penaksiran Cadangan Karbon Hutan*. Badan Standarisasi Nasional.

Suardi, H., Normah, A. B., Mui-How, P., & Mokhtar, M. (2016). Carbon Stock Estimation of Agroforestry System in Tawau. *Sabah, Transactions on Science and Technology*, *3*(1), 25–30.

Sugirahayu, L., & Rusdiana, O. (2011). Perbandingan simpanan karbon pada beberapa penutupan lahan di Kabupaten Paser, Kalimantan Timur berdasarkan sifat fisik dan sifat kimia tanahnya. *Journal of Tropical Silviculture*, *2*(3), 149–155.

Susanti, A., Khalil, M., & Sufardi, S. (2021). Evaluasi Cadangan Karbon Tanah pada Beberapa Tipe Penggunaan Lahan Kering di Kecamatan Blang Bintang Kabupaten Aceh Besar. *Jurnal Ilmiah Mahasiswa Pertanian*, *6*(2), 69–78.

Syah, R. F. (2017). Analisa Kebijakan Sektor Lingkungan: Permasalahan Implementasi Kebijakan Pengelolaan Kawasan Hutan di Indonesia. *Journal Of Governance*, *2*(1), 2–17.

Tarnocai. (2009). Soil Organic Carbon Pools In The Northern Circumpolar Permafrost Region. *Global Biogeochemical Cycles*, *23*(11), 1–11.

Wahyuni, H., & Suranto, S. (2021). Dampak deforestasi hutan skala besar terhadap pemanasan global di indonesia. *Jurnal ilmiah ilmu pemerintahan*, *6*(1), 148–163.