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Research Article

Analysis of Biomass Organic and Inorganic Carbon Stocks in Silokek Karst Geopark Area, Sijunjung Regency

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Abstract

Climate change caused by increasing greenhouse gas emissions, especially CO2, and deforestation, is an urgent global issue. The REDD+ program initiated by the UN aims to reduce carbon emissions and increase carbon storage in forests. This research aims to measure and analyze biomass and organic and inorganic carbon reserves in the Silokek Geopark area, Sijunjung Regency. The method used in this research is non-destructive sampling and using a destructive sampling method. Transects were carried out using the transect method using purposive sampling and were made in 10 plots 100 m long with square plots measuring 10x10 m for trees, 5x5 m for saplings, and 2x2 m for undergrowth. Next, the limestone samples used the chip sampling method and XRF analysis. The research results showed that the total organic biomass was 326,748 tons/ha, carbon reserves were 153,571 tons/ha, and carbon absorption was 563,607 tons/ha, which is categorized as high. The inorganic carbon content in the Silokek Geopark karst area is 4,908.07 tons/ha and inorganic carbon absorption is 18,012.60 tons/ha.

Keywords: Biomass, carbon stock, CO_2 absorption, Geopark Silokek, karst.

1. Introduction

Climate change caused by increasing greenhouse gas emissions, especially CO_2, and deforestation is an urgent global issue and one of the threats to human populations and organisms on earth (Van de Perre *et al.,* 2018). The REDD+ program initiated by the UN aims to maintain forest carbon storage, by slowing and inhibiting the increase in carbon emissions and providing forest protection, and reducing carbon caused by deforestation (Keohane and Georgia, 2016). In general, tropical forest ecosystems convert more atmospheric carbon into biomass than any other terrestrial ecosystem on earth in any given year (Marvin et al. 2014). Trees in the forest have the potential to store carbon through the process of photosynthesis, where trees sequester carbon in the air and store it in tree body parts such as trunks, branches, and leaves in the form of biomass. According to Danardono et al. (2018) stated that karst is a natural landscape with caves and has the ability to absorb carbon dioxide (CaO et al., 2018; Danardono et al., 2019). Carbon absorbed in karst areas is known as inorganic carbon which is absorbed through the process of forming karst landscapes called karstification (Cao et al., 2018).

Biomass is defined as the total mass or weight of all living creatures in an area at a given time. Carbon reserves are the total quantity of carbon or biomass stored in a component, such as plant, soil, or inorganic biomass in a certain area. Carbon absorption refers to the process by which ecosystems absorb CO_2 from the atmosphere. Carbon dioxide (CO_2) is absorbed by plants during photosynthesis and converted into organic carbon, or carbohydrates, which are then stored in the plant body's biomass (Karim *et al.,* 2019). The karst ecosystem is one type of ecosystem that can absorb a substantial amount of carbon. The Silokek Karst Geopark is a karst forest that can produce both organic and inorganic carbon in the ecosystem (Danardono *et al.,* 2018). Karst is a natural terrain containing caves that can absorb carbon dioxide (Cao *et al.,* 2018; Danardono *et al.,* 2019).

Based on research conducted in Bantimurung Bulusaraung National Park (Central Sulawesi) indicates that karst forests have a biomass potential ranging from 11.35 to 56.26 tons/ha (Syahrir *et al.,* 2019). Furthermore, based on the West Papua karst area, the predicted biomass is 26.4 tons/ha (Rozak *et al.,* 2021). Moreover, studies conducted in the Biduk-Biduk Karst area of East Kalimantan revealed that the potential for organic carbon stock was 7773.358 tons/ha, whereas inorganic carbon intake was 9026.54 tons/year (Danardono *et al.,* 2022). This shows that karst areas an important role in the carbon cycle in Indonesia, both organic and inorganic.

Based on previous research in the Silokek Geopark area by Pertiwi and Chairul (2024) regarding the analysis of tree strata plant vegetation in the Silokek Karst area, there is a diversity strata (H') of 2.85 which is categorized as medium. This research can be continued by analyzing the biomass content and carbon reserves of above-ground plants and inorganic carbon in the Silokek karst area. This study aims to quantify and assess biomass and organic and inorganic carbon stocks in the Silokek Geopark area of Sijunjung Regency. This research to analyze biomass, and carbon reserves organic and inorganic carbon in the Silokek Geopark Area, Sijunjung Regency. It is hoped that the findings of this study will provide information on biomass estimates, carbon reserves, and organic and inorganic carbon absorption in the Silokek Geopark area, which can be used to improve area management and the potential for long-term biological resource development.

2. Material and Method

This study was conducted from February to May 2024 in the Silokek Geopark Area, Sijunjung Regency, West Sumatra. The research location is at coordinates 00°37'23.4"S / 100°59'22.8"E. The research plot area is 1000 m^2 and has an altitude of 354 mdpl.

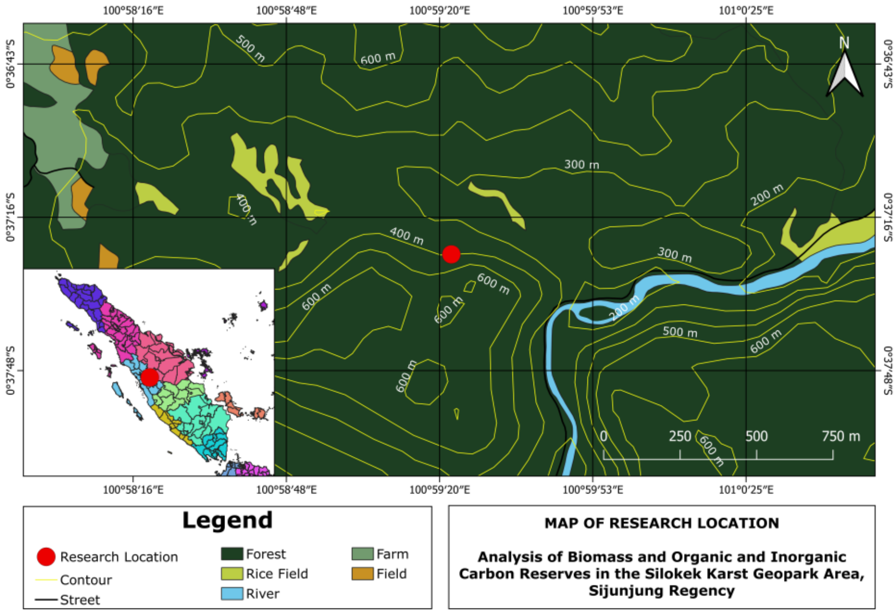

Figure 1. Location of the research area

The following tools were utilized in this study: GPS Garmin, field data sheet, thermohygrometer, soil test, lux meter, measuring tape, DBH meter, hammer and chisel, hand shovel, plant scissors, digital camera, digital scales, and calculator. The following resources were used: a herbarium kit, raffia rope, 5-kilogram plastic packing, permanent marker, writing instruments, and 70% alcohol.

This research uses a non-destructive sampling method by measuring tree diameter and saplings, and uses a destructive sampling method for undergrowth and litter (Hairiah *et al.,* 2011). Determining the location of the plot was carried out using the transect method using purposive sampling. Transects were made in 10 plots 100 m long with square plots measuring 10×10 m for trees, 5×5 m for saplings, and 2×2 m for undergrowth (Kusmana, C., 1997).

Tree biomass is measured by measuring each tree and sapling's DBH (Diameter at Breast Height) (+1.30 m above ground level). Primary data collected in the field, such as diameter at breast height and tree species names, will be used to determine biomass content. Next, samples of undergrowth were taken above the soil surface with plant scissors and weighed to determine the total wet weight, which was +300 grams. Litter samples were collected and weighed to yield a total wet weight of +300 grams (Hairiah *et al.,* 2011).

Tree sampling and sapling identification yielded species designations in Herbarium ANDA. Next, limestone rock samples were obtained using the chip sampling method, and %CaO was determined using the XRF method at the Chemistry Laboratory, UNP (Annisa, *et al.,* 2022). The Environmental Engineering Laboratory at UNAND conducted a %C analysis on soil. Environmental variables at the research location were measured at each research plot, including air temperature and humidity with a thermohygrometer, light intensity with a lux meter, and soil pH with a soil test.

Data Analysis of tree and sapling biomass measurement is calculated using the Allometric Coefficient Value Formula (a and b) (Kettrings *et al.,* 2001), for calculating upper biomass based on tree species using the calculation formula:

$$B = a\,\rho\,D^{b}$$

Description:
B = Tree and sapling biomass (kg)
D = Tree diameter and breast height (1.3 m)
ρ = density of wood each species (kg/m3)
a = constant with a value of 0.11
b = constant with a value of 2.62

To calculate the total tree biomass in one plot, use the formula:

$$\text{Total biomass} = B1 + B2 + \ldots + Bn$$

Description:
Total biomass = total biomass of all species
B1 = biomass of spesies ke-1
B2 = biomass of species ke-2
Bn = biomass of species ke-n

Measurement of undergrowth and litter biomass is according to (Hairiah *et al.,* 2011), the formula for calculating undergrowth and litter biomass is:

$$\text{Total B (g)} = \frac{\text{BK subexample (g)}}{\text{BB subexample(g)}} \times \text{Total BB(g)}$$

Description:
Total B = total biomass (g)
Total BB = Total wet weight biomass (g)
BK subexample = Dry weight of the sample (g)
BB subexample = Wet weight of the sample (g)

Measurement of carbon stocks is calculation of carbon reserves uses the formula (Hairiah *et al.,* 2011):

$$C = 47\% \times B$$

Description:
C = Carbon content in biomass (ton/ha)
B = Biomass (kg)
47% = Carbon constant according to SNI 7724:2011

Measurement of Carbon Dioxide (CO_2) absorption calculations can be using the results of carbon stock (C-stock) calculations. The formula for calculating CO_2 absorption (IPCC, 2013) is as follows:

$$EC = 3.67 \times C$$

Description:
EC = CO_2 absorption (ton CO_2/ha),
3.67 = Relative molecular value (MR CO_2 to carbon: 44/12 (ton CO_2/ton C),
C = Stored carbon reserves (ton C/ha)

Measurement of inorganic carbon in limestone materials using the formula (Danardono *et al.,* 2019):

$$MC = \left[\frac{\text{Ar C}}{\text{Mr CaCO3}} \times \frac{\text{Mr CaCO3}}{\text{Mr CaO}} \times \%\text{CaO} \times \text{BJ CaCO3} \times \text{V CaCO3} \right]$$

Description:
MC = mass of carbon in limestone (kg)
Ar C = relative atomic mass of carbon (12 g/mol)
Mr $CaCO_3$ = relative atomic mass of $CaCO_3$ (100 g/mol)
Mr CaO = relative atomic mass of CaO (56 g/mol)
%CaO = percentage of CaO content in limestone resulting from laboratory analysis
BJ $CaCO_3$ = specific gravity of $CaCO_3$ (2.71 g/cm^3)
V $CaCO_3$ = volume of limestone

3. Results and Discussion

3.1. Results

Based on the research that has been carried out, a total of biomass, carbon reserves, and organic carbon absorption in organic plants. Data on the results of organic plants can be seen in Table 1.

Table 1. Biomass, Carbon Stocks, and Carbon Absorption in Organic Plants

Strata	Biomass (ton/ha)	Carbon Reserves (ton/ha)	Carbon Absorption (ton/ha)
Trees	303.963	142.863	524.306
Sapling	21.702	10.200	37.433
Undergrowth and Litter	1.083	0.509	1.868
Total	**326.748**	**153.571**	**563.607**

Table 2. Organic Carbon of Trees

No	Species name	Family	Biomass (ton/ha)	Carbon reserves (ton/ha)	Carbon absorption (ton/ha)
1.	*Ficus stricta* (Miq.) Miq.	Morac	220,471	103,622	380,291
2.	*Monocarpia euneura* Miq.	Annonac	17,919	8,422	30,909
3.	*Diospyros* sp.	Ebenac	15,857	7,453	27,351
4.	*Ficus variegata* Blume	Morac	10,051	4,724	17,337
5.	*Vitex pinnata* L.	Lamiac	8,360	3,929	14,420
6.	*Syzygium* sp.	Myrtac	5,198	2,443	8,966
7.	*Phoebe lucida* Blume	Laura	4,828	2,269	8,328
8.	*Pterospermum javanicum* Jungh.	Malva	4,443	2,088	7,663
9.	*Garcinia* L.	Clusia	3,756	1765	6,478
10.	*Croton argyratus* Blume	Euphorbi	3,258	1,531	5,619

No	Species name	Family	Biomass (ton/ha)	Carbon reserves (ton/ha)	Carbon absorption (ton/ha)
11.	*Paranephelium xestophyllum* Miq.	Sapind	2,692	1,265	4,643
12.	*Sterculia cordata* Blume	Malva	1,333	0,627	2,300
13.	*Alstonia* sp.	Apocyna	0,887	0,417	1,529
14.	*Eurycoma longifolia* Jack	Simarouba	0,789	0,371	1,361
15.	*Ficus sinuata* Tunb.	Morac	0,769	0,362	1,327
16.	*Artocarpus elasticus Reinw*. Ex Blume	Morac	0,695	0,326	1,198
17.	*Knema laurina (Blume)* Warb.	Myristi	0,600	0,282	1,035
18.	*Dialium* sp.	Faba	0,476	0,224	0,822
19.	*Nephelium lappaceum* L.	Sapind	0,474	0,223	0,818
20.	*Mallotus nudiflorus* (L.) Kulju & Welzen	Euphorbi	0,383	0,180	0,660
21.	*Aporosa benthamiana* Hook.f	Phyllantha	0,383	0,180	0,660
22.	*Ficus padana* Burm.f.	Morac	0,341	0,160	0,589
	Total (ton/ha)		**303,963**	**142,863**	**524,306**

Table 3. Organic Carbon of Sapling

No	Species name	Family	Biomass (ton/ha)	Carbon reserves (ton/ha)	Carbon absorption (ton/ha)
1.	*Diospyros* sp.	Ebena	2,317	1,089	3,996
2.	*Drypetes* sp.	Putranjiva	1,822	0,857	3,144
3.	*Syzygium* sp.	Myrta	1,397	0,657	2,410
4.	*Polyalthia* sp.	Annona	1,121	0,527	1,934
5.	*Pometia pinnata* J.R.Forst. & G.Forst.	Sapinda	0,960	0,451	1,656
6.	*Pterospermum javanicum* Jungh.	Malva	0,959	0,451	1,655
7.	*Artocarpus rigidus* Blume	Mora	0,840	0,395	1,449
8.	*Mallotus peltatus* (Geiseler) Muell. Arg.	Euphorbia	0,834	0,392	1,439
9.	*Croton argyratus* Blume	Euphorbia	0,792	0,372	1,366
10.	*Phoebe lucida* Blume	Laura	0,749	0,352	1,291
11.	*Dysoxylum alliaceum* Blume	Melia	0,731	0,344	1,261
12.	*Lithocarpus* sp.	Faga	0,709	0,333	1,222
13.	*Elaeocarpus angustifolius* Blume	Ealeocarpa	0,630	0,296	1,086
14.	*Macaranga aleuritoides* F.Muell	Euphorbia	0,626	0,294	1,080
15.	*Paranephelium xestophyllum* Miq.	Sapind	0,605	0,285	1,044
16.	*Monocarpia euneura* Miq.	Annona	0,585	0,275	1,010
17.	*Ficus stricta* Miq.	Mora	0,574	0,270	0,990
18.	*Ficus variegata* Blume	Mora	0,574	0,270	0,990
19.	*Vitex pinnata* L.	Lamia	0,529	0,249	0,913
20.	*Aglaia lawii* (Wight) C.J.Saldanha.	Melia	0,527	0,248	0,910
21.	*Annona* sp.	Annona	0,523	0,246	0,902

No	Species name	Family	Biomass (ton/ha)	Carbon reserves (ton/ha)	Carbon absorption (ton/ha)
22.	*Nephelium* sp.	Sapind	0,477	0224	0,823
23.	*Artocarpus elasticus* Reinw. Ex Blume	Mora	0,430	0,202	0,743
24.	*Sandoricum koetjape* Burm.f.Merr	Melia	0,375	0,176	0,646
25.	*Palaquium obovatum* (Griff.) Engl.	Sapota	0,339	0,159	0,585
26.	*Neonauclea calycina* (Bartl. Ex. DC.)	Rubia	0,269	0,127	0,465
27.	*Macaranga triloba* (BI.) Muell Arg.	Euphorbia	0,264	0,124	0,455
28.	*Dysoxylum* sp.	Melia	0,255	0,120	0,440
39.	*Polyalthia subcordata* Blume	Annona	0,214	0,101	0,370
30.	*Litsea* sp.	Laura	0,201	0,094	0,347
31.	*Alstonia scholaris* (L.) R. Br.	Apocyna	0,199	0,094	0,344
32.	*Sterculia rubiginosa* Vent.	Malva	0,174	0,082	0,299
33.	*Alstonia* sp.	Apocyna	0,099	0,047	0,171
	Total (ton/ha)		**21,702**	**10,200**	**37,433**

Table 4. Organic Carbon of Undergrowth and Litter

Plot	Biomass (ton/ha)	Carbon reserves (ton/ha)	Carbon absorption (ton CO_2/ha)
1	0,809	0,380	1,396
2	0,030	0,014	0,051
3	0,024	0,011	0,042
4	0,025	0,012	0,043
5	0,034	0,016	0,059
6	0,029	0,014	0,050
7	0,027	0,013	0,046
8	0,036	0,017	0,062
9	0,034	0,016	0,059
10	0,035	0,016	0,060
Total (ton/ha)	**1,083**	**0,509**	**1,868**

The relationship between biomass and diameter in the figure above 2 shows positive results.

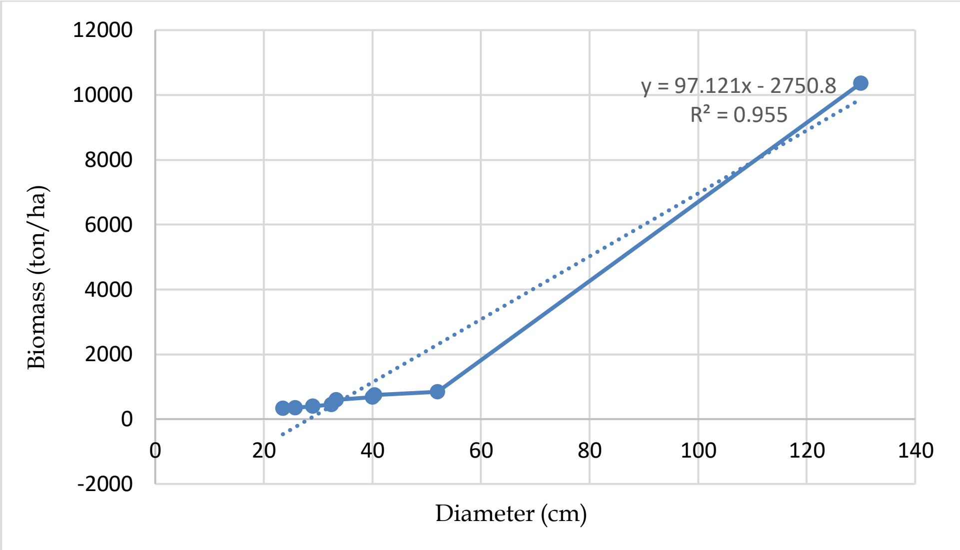

Figure 2. Relationship between biomass and diameter

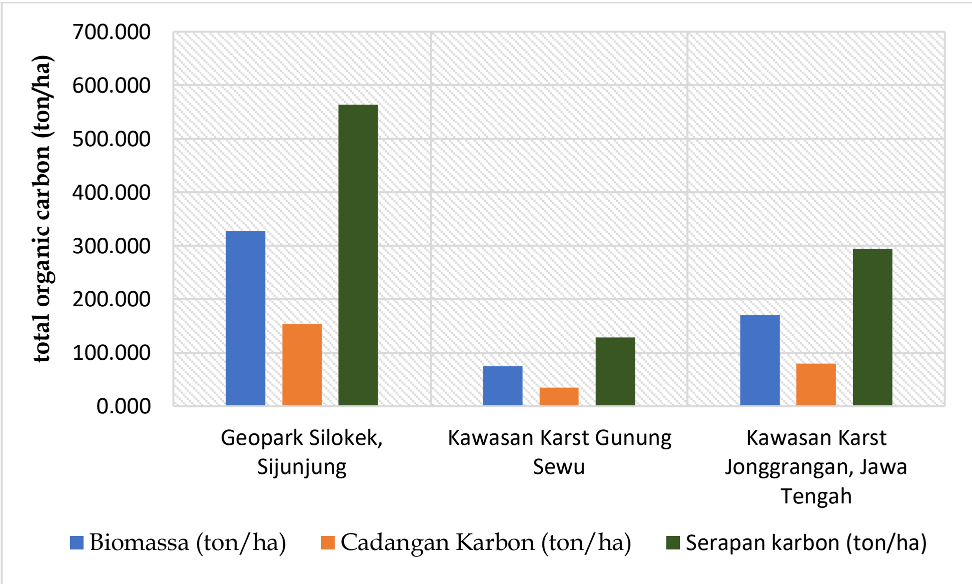

Figure 3. Comparison of biomass, carbon reserves, and carbon absorption from the three different locations

Based on the results of inorganic biomass in the karst *Geopark* Silokek area, that has been carried out the inorganic total carbon can be seen in Table 2.

Table 5. Inorganic Carbon Content

No	Sample	%CaO	Inorganic Carbon (ton/ha)
1.	Sample 1	90.087	1554.80
2.	Sample 2	96.879	1672.02
3.	Sample 3	97.414	1681.25
	Total (ton/ha)		**4908.07**

Table 6. Environmental Factor Measurement

The research area	Environmental factor	Unit
Geopark Silokek Area, Sijunjung Regency	Temperature	27.9°C
	Air humidity	75.9%
	Light intensity	8.86%
	pH	7

3.2. Discussion

Based on the research that has been carried out, a total of biomass, carbon reserves, and organic carbon absorption in organic plants. Data on the results of organic plants can be seen in Table 1. According to Table 1, the biomass of organic carbon in plants is 326,748 tons/ha, while in trees it is 303.963 tons/ha, saplings are 21.702 tons/ha, and undergrowth plants and litter are approximately 1.083 tons/ha. A tree biomass study was conducted because trees absorb more carbon than sapling strata, undergrowth, and litter, as evidenced by the fact that the older the tree, the bigger its diameter and height. Trees with diameters of more than 20-50cm contribute significantly to biomass analysis results, accounting for approximately 69% of total biomass.

The relationship between tree biomass (the total mass of organic material generated by a tree) can be understood as implying that the larger the tree's diameter, the greater the biomass produced. Apart from diameter, biomass correlates positively with specific gravity. This positive link was demonstrated in tree growth, with larger trees producing more biomass than smaller ones. This is because larger trees have more woody tissue, stems, and leaves, which all contribute to the tree's overall biomass. Trees take CO_2 from the atmosphere through photosynthesis and store it as biomass (Chave, *et al.,* 2014). A vegetation's stem diameter is connected to its biomass specific gravity is also related to biomass (Tuah, 2017).

The carbon reserves of organic carbon in plants are 153.571 tons/ha, while in trees it is 142.863 tons/ha, saplings are 10.200 tons/ha, and undergrowth plants and litter are approximately 0.509 tons/ha. Meanwhile, trees with a diameter of the research results show that the biomass and carbon reserves of trees and saplings are higher than those of undergrowth plants and litter because trees are photosynthetically active plants. The research area's average light intensity of 8.86% (table 6) allows trees to create new biomass throughout their lives. Based on research from Pan *et al.* (2011) trees with a strong structure and roots in the soil can grow larger and produce more biomass. In contrast to the undergrowth, the forest conditions at the research site are relatively dense, making it difficult for the undergrowth to absorb sunlight for photosynthesis, resulting in a modest biomass. Litter has a shorter life cycle compared to trees, because the process of decomposition and decomposition by microorganisms is relatively short.

Photosynthesis has an important role in determining the amount of carbon stores. Plants collect carbon from the air and convert it to organic compounds via photosynthesis (Syahrir *et al.,* 2019). Photosynthesis findings are utilized to promote vertical (height) and horizontal (diameter) growth in trees. The biomass contained in a forest area shows the productivity strata in that forest, because the formation of plant body parts is related to biomass, where the longer the age of the plant, the greater the biomass produced. Biomass value is positively related to carbon reserves, where the higher the biomass value, the higher the carbon reserves.

According to table 1, the intake of organic carbon in plants is 563.607 tons/ha, while in trees it is 524.306 tons CO_2/ha, saplings are 37,433 tons CO_2/ha, and undergrowth plants and litter are approximately 1.868 tons CO_2/ha. This contrasts with research in the Gunung Sewu Karst area (Bantul, Gunung Kidul, Wonogiri, and Pacitan), which found a total biomass value of 74.780 tons/ha, carbon stocks of 35.147 tons/ha, and carbon intake of 128.988 tons/ha (Haryono *et al.,* 2016). Furthermore, studies were conducted in the Jonggrangan Karst area of Central Java, which had a total biomass value of 170.328 tons/ha, carbon reserves of 80.054 tons/ha, and carbon absorption of 293,799 tons/ha (Putro, 2010).

This research illustrates that trees can absorb more carbon than saplings, undergrowth, and litter. The value of carbon absorption in plants describes the plant's ability to absorb CO_2 from the surrounding air. The increase in diameter is driven by the storage of biomass produced by CO_2 conversion, which becomes greater as the tree absorbs more CO_2 (Manafe *et al.,* 2016). The largest part of a tree that can store more carbon is the trunk (Stephenson, *et al*., 2014).

The stem is a place to store food reserves from photosynthesis and is the woody part (Cahyaningrum *et al.,* 2014). Trees absorb carbon from the environment through photosynthesis. The carbon is absorbed by the leaves, which subsequently perform photosynthesis and spread to other parts of the tree. The number and density of trees, tree diameter, kind, and canopy, as well as climatic parameters including sunlight, water content, temperature, and soil fertility, all impact biomass values and CO_2 absorption in different research locations. The amount of biomass is determined by diameter, plant height, wood density, and soil fertility (Sedjarawan *et al.,* 2014).

Based on the analysis carried out by the REDD+ Task Force (2012), the classification of carbon stocks in forest ecosystems consists of low strata such as underground and litter (<35 tons/ha), medium strata such as sapling (35-100 tons/ha), and high strata such as trees (>100 tons/ha). The amount of carbon stocks is strongly influenced by biomass. Based on the results at the research location, it is known that the total carbon reserves are 153,571 tonnes/ha which is categorized as high. Biomass has a significant impact on carbon stock levels (Uthbah *et al.,* 2017).

Based on the comparison in the figure 3, it shows that the values of biomass, carbon reserves, and carbon absorption at the three research locations do not show significantly different total values. The difference in value depends on the volume and area of the area. The Silokek Geopark covers 1300 km^2 of karst terrain. This differs from the research by Haryono *et al.* (2016) in Mount Sewu Karst with karst volume area (29 km^2) and Jonggrangan Karst (1300 km^2). These differences in values indicate that although the values per unit area may be similar, the total biomass, carbon stock, and carbon sequestration will differ significantly due to differences in area size. Therefore, it is important to consider factors such as area size, vegetation type, and environmental conditions in the analysis and comparison of biomass and carbon stocks in different karst areas.

Based on Table 5 it is known the differences in CaO content in the three rock samples in Table 2 above are due to differences in rock composition and influencing environmental factors. The carbon content value at the research location is approximately 4908.07 tons per hectare. Table 2 shows that the research location has an inorganic carbon content of 4908.07 tons/ha and a carbon absorption of 18012.60 tons/ha. This differs from other karst sites in Biduk-Biduk Karst, East Kalimantan, in that the inorganic carbon concentration is 9026.54 tons/ha and the carbon intake is 33127.40 tons/ha (Danardono *et al.,* 2019). The research area's inorganic carbon absorption values vary depending on volume and rock composition.

The results of the research show that the value of inorganic carbon content is higher than the value of organic carbon, that explains that the potential for carbon storage in rock formations is one of the highest carbon reserves on earth below ocean carbon reserves and organic carbon. Inorganic carbon rocks transform into a highly stable and durable form, playing a crucial role in long-term carbon storage. In the context of climate change, its influence on the carbon trapped in rocks can be significant. Due to its stability, carbon trapped in these rocks can persist on Earth for very long periods, functioning as a more durable carbon reserve compared to organic carbon, which is more easily decomposed (Schlesinger & Bernhardt, 2013). The higher value of inorganic carbon content is due to the influence of the volume and mass of this rock, which significantly surpasses the volume and mass of organic material on the soil's surface or in living species' biomass (a long-term geological process). In addition, the carbonate component in rocks is particularly chemically stable and is not easily degraded or changed by biological processes. In contrast, organic carbon is more susceptible to decomposition by microorganisms, oxidation, and other processes that convert it to carbon dioxide (CO_2) or methane (CH_4) (Schlesinger & Bernhardt, 2013).

Conclusion

Based on the results of research conducted regarding biomass analysis and organic and inorganic carbon reserves in the Silokek Geopark karst area, Sijunjung Regency, the following conclusions can be drawn: The total organic biomass in the Silokek Geopark karst area is 326,748 tons/ha. The total organic carbon reserves in the Silokek Geopark karst area are 153,571 tons/ha. The organic carbon absorption in the Silokek Geopark karst area is 563,607 tons/ha. The inorganic carbon content in the Silokek Geopark karst area is 4,908.07 tons/ha and the inorganic carbon absorption is 18,012.60 tons/ha. The organic and inorganic biomass in the Silokek Geopark area are categorized as high, thus contributing to reducing the amount of CO_2 in the atmosphere and mitigating climate change.

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