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Estimation of carbon sequestration of undergrowth and litter in post-burn and unburned peatland in agrosilvofishery demonstration plots, Sepucuk, Ogan Komering Ilir

Pendugaan penambatan karbon tumbuhan bawah dan serasah di lahan gambut pasca terbakar dan tidak terbakar pada petak demonstrasi agrosilvofishery, Sepucuk, Ogan Komering Ilir

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ABSTRAK

Penelitian ini bertujuan untuk menghitung biomassa dan penambatan karbon pada kondisi lahan tidak terbakar dan setelah terbakar pada lahan gambut. Penelitian dilaksanakan bulan Januari 2023 sampai Februari 2023 di petak demonstrasi Restorasi Gambut Agrosilvofishery Sepucuk, Kabupaten Ogan Komering Ilir, Sumatera Selatan. Pengamatan biomassa pada serasah dan tumbuhan bawah dilakukan pada kondisi vegetasi baik, sedang dan buruk dengan metode destruksi pada petak pengamatan berukuran 0,5 m x 0,5 m, pengulangan dilakukan sebanyak 3 kali, dan untuk setiap kondisi tanaman juga diulang sebanyak 3 kali. Hasil penelitian memperlihatkan bahwa kondisi lahan pasca terbakar memiliki rataan nilai cadangan karbon tumbuhan bawah dan serasah lebih tinggi. Tumbuhan bawah memiliki nilai karbon sebesar 1,95 ton/ha dan serasah memiliki nilai sebesar 0,50 ton/ha. Kondisi pada lahan tidak terbakar memiliki nilai yang lebih rendah, pada tumbuhan bawah memiliki nilai cadangan karbon sebesar 0,80 ton/ha dan untuk serasah memiliki nilai cadangan karbon sebesar 0,47 ton/ha. Hasil perbandingan menunjukkan pada sampel vegetasi tumbuhan bawah purun dan senduduk memiliki hasil perbedaan yang terlihat nyata, sedangkan untuk jenis sampel serasah tanaman menunjukkan hasil nilai tidak memiliki perbedaan yang nyata.

Kata kunci: lahan gambut, biomassa, karbon

ABSTRACT

The research aimed to estimate biomass and carbon sequestration in unburned and post-burn peatlands. Data analysis was conducted from January 2023 to February 2023 in Sepucuk Agrosilvofishery Peatland Restoration demonstration plots, Ogan Komering Ilir, South Sumatra. The biomass and litter of understory vegetation were observed in good, medium, and poor vegetation conditions using the destructive method on 0.5 m x 0.5 m observation plots with 3 repetitions, and with 3 repetitions for each vegetation condition. The research depicts that post-burn peatland has a higher average carbon storage of understory vegetation and litter, 1.95 tons/ha for understory vegetation and 0.50 tons/ha for litter. However, unburned peatland has lower average carbon storage, 0.80 tons/ha for understory vegetation and 0.47 tons/ha for litter. The comparison depicts that Purun and Sembangun understory vegetation samples have significantly different results, while the vegetation litter samples have insignificantly different results.

Keywords: peatland, biomass, carbon

INTRODUCTION

Peat formation is a process of transformation and translocation (Noor et al., 2015) dan The peat formation process takes a very long time. Peat land is an organic material that is formed naturally from plant remains that are undergoing a decomposition process peat swamp forests have an important role in efforts to maintain environmental balance as a source of carbon reserve deposit (Agus, et al., 2013; Husnain, et al., 2014). Peat with a thickness of 100 cm has potential carbon reserves of 400-700 t/ha (Dommain et al., 2014).

Peatland ecosystems are currently experiencing a lot of functional degradation as a result of both long-term drought processes (Syaufina, 2008) and continued fires (Taufik et al., 2015). Tacconi (2003) states that the peatland fire process usually starts with a surface fire, that is, burning all the fuel above the surface, and then if possible the fire will spread slowly below the surface or peat.

Wildfires are one of the main causes of forest destruction, disturbing forest sustainability (Silvana et al., 2019). The impact of surface fires is the burning of most of the surface biomass as higher level vegetation, litter and native peat undergrowth (Silvana et al., 2019). The impact of light forest fires is that burned plants can still recover by regrowing (resprouting), while at severe levels of fire, it is possible that burned vegetation will be very difficult to grow, so that in these locations you will often find land without vegetation.

If land is badly burned, puddles will form when it rains, this condition can be a medium for the movement/dissemination of seeds from outside and then into the land. The new vegetation that most often appears as a result of dispersal through water is sempu (*Melastoma malabatricum*) and ferns (*Stenochlaena palustris*). The further impact is that the succession process or population development and composition of peat forest vegetation is disrupted or reduces biodiversity (Tacconi, 2003) or even interrupted, increased soil subsidence (Astika et al., 2022), then pioneer vegetation appears. On the other hand, The peat ecosystem is able to provide forest products (wood and non-wood), store and supply water, store carbon, and is a habitat for biodiversity with various types of rare flora and fauna (Astiani, 2016). In natural forest conditions, peatlands function as a carbon sequester thereby contributing to reducing greenhouse gases in the atmosphere (Emmy et al., 2017).

The plot demonstration was carried out as an effort to improve the condition of degraded peatlands caused by the 2015 fires by building a Paludiculture Model Plot on a 6 hectare plot of land on Kedaton Village, Kayuagung sub-district, Ogan Komering Ilir Regency, South Sumatra.

The Model Plot is in the form of a Demonstration Plot (Demplot) which was built in 2017 covering an area of 4 hectares and was expanded by 6 hectares in 2019 so that the total area of the Demonstration Plot is currently 10 hectares. The development of the Model Plot was funded by the Peat Restoration Agency (Sumatra Paludiculture Consortium Team, 2019).

Agrosilvofishery is a peat-friendly integrated cultivation pattern that has been developed by BP2LHK Palembang since 2002, a combination of agricultural cultivation, forestry and fisheries in one stretch of land. The forestry vegetation used for revegetation is a type of tree that is adaptive to extreme deep inundation, namely belangeran (*Shorea balangeran*).

The composition and structure of vegetations can be used to see thedominance of a plant species in the area (Kardiannor et al,. 2022), as an indicator of soil fertility because the litter produced in the soil can increase soil fertility (Naemah et al., 2020), also as a source of carbon anchorage above the soil surface (Junaedi et al., 2020.).

Astiani et al. (2021) revealed that the level of damage to peat swamp forests had the most significant effect on the growth, type and density of vegetation. The greatest damage to peatland vegetation is surface fires on land followed by ground fire (Silvana et al., 2019). Furthermore, peatland degradation, edge effect, drainage ditches shift species composition on tropical peatland of West Kalimantan (Astiani 2016; Astiani et al., 2017). The objective of this research was to estimate biomass and carbon sequestration in unburned and post-burn peatlands.

MATERIALS AND METHODS

Research Preparation

Research preparation consisted of pre-survey activities and preparation of materials and tools for research. A pre-survey was carried out to determine the condition of understory vegetation and litter in the good, medium and poor categories in the demonstration plot of Agrosilvofishery Peatland Restoration. Preparation of materials and tools was to prepare all necessary materials and tools for use in the field.

Research Location

The research was carried out on the Agrosilvoishery Peatland Restoration Demonstration Plot, Sepucuk, Kayuagung, Ogan Komering Ilir Regency covering an area of 4 hectares. This research was part of the carbon balance research on the demonstration plot (Figure 1).

Research Observations

Observations of understory vegetation biomass and litter were carried out in good, medium and poor vegetation conditions using the destruction method in observation plots of 0.5 m x 0.5 m with repetition 3 times, and for each plant condition it was also repeated 3 times. Observation parameters consist of criteria for main vegetation condition, biomass, organic C content and carbon reserves of litter and undergrowth.

Research Data Analysis

To determine the differences in the carbon values of litter and understory vegetation which influence the value of carbon sequestration in post-burnt and unburnt land conditions, statistical analysis was carried out using the T-test.

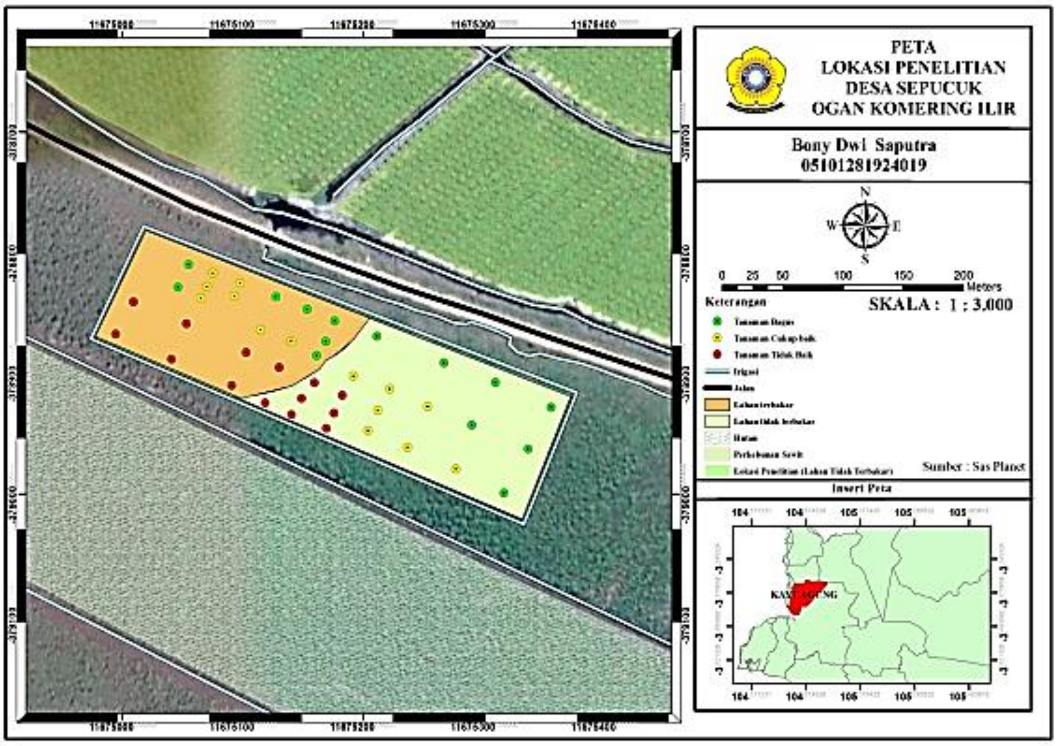

Figure 1. Research and sample sites

RESUTLS

The Agrosilvoishery Peatland Restoration Demonstration Plot

The Agrosilvoishery Peatland Restoration Demonstration Plot, Ogan Komering Ilir Regency was part of the KHG peatland landscape of the Burnai River - Sibumbung River and has experienced repeated peat fires. The last fire in the Burnai River - Sibumbung River KHG occurred in 2015. In 2017, an Agrosilvofishery Demonstration Plot was created with BRG funds to become a model for integrated peatland use with the 3 Rs (Rewetting, Revegetation and Revitalization) on an area of 6 ha.

Criteria for Undergrowth Growth Conditions

The success of this demonstration plot was quite good with the growth of the main vegetation, namely belangeran (*Shorea Balangeran*). However, in 2019, a fire occurred in part of this demonstration plot, around 1.7 hectares, and the remaining 2.3 hectares was not burned. Peatland fires in the Agrosilvoishery Peatland Restoration Demonstration Plot affect the growth of understory vegetations.

Value of Purun Carbon Sequestration on Burned and Unburnt Peatland

Observation results showed that there were two dominant types of understory vegetation around the belangeran (*Shorea Balangeran*) stands, namely purun (*Lepironia articulate*) and senduduk (*Melastomataceae malabathricum*). When compared with the research of Simbolon (2004) two years after the second fire in the Kelampangan peat forest, Central Kalimantan, it was recorded that *Syzygium sp* and other types of ferns were still found which had a cover class of around 20 %. The results of observing biomass and carbon sequestration in understory vegetation using 3 criteria (Table 1) for observing understory Purun vegetation on burned and unburned peatlands as presented in Table 2. Tabel 2 showed than the results of calculating the average carbon sequestration of understory vegetation on burned land produce a higher value than on unburned land, around 1.05 tonnes per hectare. Relatively similar conditions were also found in the average carbon sequestration for understory vegetation. The weight of the understory vegetation on burned land was higher than on unburned land with a difference of around 1.25 tonnes per hectare.

Table 1. Criteria for understory vegetation conditions

Understory Vegetation Conditions (%)	Criteria for Understory Vegetation
> 50	Good
50	Moderate
< 50	Not Good

Source: Nanlohy dan Fajrianto (2022)

Table 2. Value of purun carbon sequestration on burned and unburnt peatland

Land Conditions	Criteria for Undergrowth	Dry Weight (tons/ha)	C Organic (%)	Carbon Sequestration (tons/ha)
	Good	2.34	0.48	1.12
The land was not burned	Moderate	2.25	0.68	1.53
	Not Good	2.14	0.78	1.67
Average		2.24	0.64	1.44
	Good	2.30	0.90	2.07
Burned land	Moderate	2.24	1.21	2.71
	Not Good	2.23	1.21	2.70
Average		2.26	1.10	2.49

Value of Senduduk Carbon Sequestration on Burned and Unburnt Peatland

The results of observing biomass and carbon sequestration in understory vegetation using 3 criteria (Table 1) for observing understory senduduk vegetation on burned and unburned peatlands as presented in Table 3. The carbon sequestration value in Senduduk vegetation (Table 3) was lower when compared to the carbon sequestration value in purun vegetation (Table 2), both on burned and unburned land. Tabel 3 shows that the highest average value of carbon sequestration in unburned peatlands was in good condition (0.19 tons/ha) and in burned peatlands in poor conditions, the vegetation was not good (1.40 tons/ha). The average value of carbon storage in unburned peatlands was lower than burned peatlands, with a difference of around 1.25 tons/ha.

Value of Litter Carbon Sequestration on Burned and Unburned Peatland

Litter as a result of organic material, especially dead understory vegetation, was often found on peatland floors. Physically, litter could be easily seen and could easily differentiate between litter and peat soil. The results of litter calculations on burned and unburned land were presented in Table 4. Tabel 4 shows the average value of carbon sequestration in litter on both burned and unburned land shows no different values, namely on unburned land with a value of 0.47 tonnes per hectare and on burned land with a value of 0.50 tonnes per hectare. The results of the Paired T-Test test for the carbon sequestration values of understory vegetation and litter were presented in Table 5, which showed that carbon sequestration do not have a significant difference.

Table 3. Value of senduduk carbon sequestration on burned and unburnt peatland

Peatland Conditions	Criteria For Understory Vegetation	Dry Weight (tons/ha)	C Organic (%)	Carbon Sequestration (tons/ha)
Not burned	Good	0.93	0.20	0.19
	Moderate	0.86	0.19	0.16
	Not Good	0.81	0.15	0.12
Average		0.86	0.18	0.15
Burned	Good	1.80	0.57	1.03
	Moderate	1.79	1.71	1.27
	Not Good	1.75	1.09	1.91
Average		1.78	0.79	1.40

Table 4. Value of litter carbon sequestration on burned and unburned peatland

Peatland Conditions	Criteria For Understory Vegetation	Dry Weight (tons/ha)	C Organic (%)	Carbon Sequestration (tons/ha)
Not burned	Good	2.97	0.15	0.45
	Moderate	2.82	0.17	0.48
	Not Good	2.81	0.17	0.48
Average		2.86	0.16	0.47
Burned	Good	2.75	0.18	0.50
	Moderate	2.71	0.18	0.49
	Not Good	2.70	0.19	0.51
Average		2.73	0.18	0.50

Table 5. Paired T-test test results with carbon sequestration values

	T	*Df*	*Sig. 2 tailed*
Purun	15,625	2	0,004
Senduduk	4,411	2	0,048
Litter	2,598	2	0,122

DISCUSSION

The results of the pre-survey showed that the growth of understory vegetation on burned and unburned land does not look the same, so to get the best data, criteria for understory vegetation condition were created which were presented in this research, which refers to Nanlohy & Fajrianto (2022). The criteria in the data were very good at representing the growth conditions of understory vegetation as a result of peatland fires at the research location.

The carbon content stored on the top surface of the land was determined by the biomass and percent of organic waste produced, this was because the greater the biomass and the percent of carbon produced by vegetation, the greater the value of carbon reserves stored in the top layer of the land (Budiman et al., 2015).

Based on the results of field observations during the pre-survey, both on burnt and unburned land, the growth of understory vegetation had diversity, so that to produce good data, criteria for understory vegetation growth were determined, namely good, moderate and poor understory vegetation growth conditions. The determination of these conditions is in line with Nanlohy and Fajrianto (2022). The results of biomass and carbon sequestration calculations from the three criteria are made for the average value of biomass and carbon sequestration.

The average total carbon storage of lake understory vegetation on burned land has the highest total carbon sequestration with a value of 2.49 tonnes/ha and on unburned land the highest average total carbon sequestration is 1.44 tonnes/ha, or has a value difference of around 1.05 tons/ha. Several factors causing differences in biomass and total carbon values in burned and unburned land are the impact of burned land on soil nutrient availability and *Blangeran sp*. vegetation growth factors on the microclimate.

The highest mean value of biomass and total carbon sequestration in *Senduduk sp*. is on burned land with a value of 1.40 tons/ha, and the value on unburned land is 0.15 tons/ha. Relatively the same thing is also found in the data, namely that the biomass and total carbon values are higher on burned land. The average value of litter biomass at the research location shows that burned peatland has a higher value than unburned peatland. The total carbon value of litter carbon on burned land ranges from 0.49 to 0.51 tonnes/ha or with an average of 0.50 tonnes/ha. On the other hand, the total carbon value on unburned peatland ranges from 0.45 to 0.48 tonnes/ha, or an average of 0.47 tonnes/ha.

The results of the research biomass values in the agrosilvofishery demonstration plots, both purun and senduduk, were still lower compared to the research results of Prayitno et al. (2013) with the highest biomass average of around 8,857 tons C/ha and the lowest 3,333 tons C/ha on peat land. Other research by Ponisri and Anif (2023) show the total carbon stocks for litter ranged from 0,792-2,149 kg, for a total of 6,523 kg. The dominant species for storing carbon in Makbon production forests are *Ficus sp*. at the sapling level and *Guava/Syzygium sp*. at the pole and tree levels.

Furthermore, the results of research by Rositah et al. (2014) showed that the total biomass analysis of litter ranged from 31,717-61,141 kg/m^2 or 31.72-61.14 tons/ha. Other research by Ponisri and Anif (2023) show total carbon stocks for litter ranged from 0,792-2,149 kg, for a total of 6,523 kg. The dominant species for storing carbon in Makbon production forests are *Ficus sp*. at the sampling level and *Guava/Syzygium sp*. at the pole and tree levels. Carbon storage and CO_2 absorption in all peat depths ranged from: 1.73 to 2.71 tons/ha; 0.81 - 1.30 ton C/ha and 2.98 - 4.77 tons CO_2/ha (Junaedi et al., 2020) as Understorey in Peat Swamp Forest, Central Kalimantan Province.

The research results of Pariri et al. (2020) stated that the highest understory carbon sequestration was obtained in the Manilkara fasciculate stand plot at 0.807 tons C/ha, while the highest litter carbon sequestration was in the *Pometia coreacea* plot, namely 1.62 tons C/ha. The difference in litter carbon anchorage values in each stand is greatly influenced by the age of the main plant, soil and water conditions and the microclimate that is formed.

Najiyati et al. (2005), peat maturity levels vary because they are formed from different materials, environmental conditions and times. Peat that has matured will tend to be smoother and more fertile. On the other hand, immature ones contain lots of fiber and are less fertile. Soil that has a high ash content and the more it is mixed with mineral soil and has been decomposed, the greater the volume weight.

The condition of blangeran vegetation on unburned land shows very good growth and this situation is inversely proportional to burning.The good condition of the main blangeran plant will influence the growth of the lower plants.The good condition of the tree or main plant with a large trunk diameter and dense leaf condition prevents sunlight from entering the surface of the soil or undergrowth directly to support photosynthesis activities, causing conditions for undergrowth growth to be less than optimal (Lulu et al., 2018).

Vegetation diameter is a function of tree age which has a linear relationship, that is, as the tree ages, the diameter will also increase (Nofrianto et al., 2018). The growth of a vegetation will depend especially on sunlight. The addition of biomass can occur due to the photosynthesis process. Vegetations absorb CO_2 from the air and convert it into organic compounds through the process of photosynthesis and will be translocated to vegetation parts. Understory vegetation that grow on a landscape are an important force in the process of structuring ecological systems as a result of ecosystem changes.

According to Hairiah (2018), the amount of carbon sequestration in the top layer of field will be greatly influenced by the amount of biomass and % C-Organic of the vegetation. Vegetation density is also one of the factors behind the large potential carbon reserves. On post-burning land, the density of main trees has decreased due to the condition of peat soil which has experienced degradation causing poor nutrient content in post-burning soil so that the growth of main plants is hampered.

Peatland fires will initially reduce soil biodiversity, soil organic matter content and then in the short term can increase soil pH, increase N-NH^{4+}, available phosphorus, Na^+, K^+ and Mg^{2+}, reduce CEC, and soil Ca^{2+} (Firmansyah and Subowo, 2012), where naturally peat soil has low soil fertility. Based on research by Rauf (2016), the results obtained in post-burning land conditions where the pH value, C-organic content, N-total content, P-available content, K-dd content were higher, this indicated that a fire had touched peat soil material.

The condition of the physical properties of the soil in peatlands with the condition of burned land in the form of ash from burning vegetation and organic soil, this condition causes the soil to be easily eroded due to the absence of elements or clay content in the burned soil so that the elements in the land will be easily dissolved by water.

The results of the Paired T-test, paired carbon sequestration values, the results of the significance test of hypothesis testing (T test) show that the results for the purun and senduduk understory vegetation samples have significantly different results, while for the types of litter samples show insignificantly different results.

CONCLUSION

The research depicts that post-burn peatland has a higher average carbon storage of understory vegetation and litter, 1.95 tons/ha for understory vegetation and 0.50 tons/ha for litter. However, unburned peatland has lower average carbon storage, 0.80 tons/ha for understory vegetation and 0.47 tons/ha for litter. The comparison depicts that Purun and Sembangun understory vegetation samples have significantly different results, while the vegetation litter samples have insignificantly different results.

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