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Analysis of Carbon Above The Ground As The Indicator of Forest Health In Protection Forest Registers 25

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Abstract. Forest health is very important in the whole world, when global issues like air pollution, acid rain, forest fires, quality and quantity of water, and global climate change has affected the realization of a sustainable forest. Achievement of forest preservation in forest ecosystem, criteria and indicators had been widely formulated. Therefore, carbon analysis is significantly needed to figure the indicator of forest health. The aim of the research was to analyze the carbon as a forest health indicator in Protection Forest, Reg. 25. The data were collected through cluster plot based on Forest Health Monitoring (FHM) method. The calculus of the amount of stored biomass within the tree was referring to [1] is W = 0,11 x ρ x D2, 62, mean while under growth and litter biomass are gained from total dry weight. Carbon sink is based on conversion number; 0,5 out of total biomass number. The average of carbon stored in Protection Forest Reg. 25 is about 939,12 ton/ha. Carbon within the stands are contributed the most; 937, 43 ton/ha, litter carbon about 1,06 ton C/ha and undergrowth carbon is about 0,63 ton C/ha. Based on the analysis, carbon can be a health indicator of Protection Forest Register 25 with the category of ugly, moderate, and good. Cluster plots 1 and 2 classified to good category (1,232.75 ton C/ha - 1744.13 ton C/ha). As for cluster plots 3 and 4 classified to poor category (209.97 ton C/ha - 721.35 ton C/ha).

Keyword: Carbon, cluster plot, forest health indicator, protection forest register 25

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1 Introduction

The issue of global climate change is a growing phenomenon today. One of the causes of global climate change is forest degradation. According to [2], forest degradation results in increased carbon dioxide (CO2) emissions, whereas forests have the ability to absorb CO2 or known as carbon sinks.

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According to [3], the forestry sector has great potential in absorbing carbon through planting, increasing forest growth, reducing the rate of deforestation and forest fires. These functions show that the forest is one of the main elements as a regulator of the earth's temperature locally, regionally and globally.

The achievement of forest sustainability in a forest ecosystem, the criteria, and the indicators have been formulated or developed by government and non-governmental institutions in national, regional and international levels [4]. The health of forest ecosystems becomes very important throughout the world when various global issues such as air pollution, acid rain, forest fires, problems with quality and quantity of water, and global climate change have affected the realization of sustainable forests. Criteria are usually expressed as conditions or situations in the aspect of the forest whose process must be carried out, while indicators are usually expressed as something special that can be assessed in relation to the criteria [5].

The measured health indicators of forest ecosystems differed depending on forest management efforts to be achieved. This study used carbon as a health indicator of Protection Forest Register 25. The purpose of this study is to observe carbon as an indicator of the health of Protected Forests in Register 25. There is no carbon data from the Protected Forests Register 25. Therefore, a carbon analysis in this area needs to be carried out.

According to [6], the knowledge about stored carbon allows us to know the function of the area in supporting the reduction of greenhouse gas emissions which is one of the causes of global climate change. Healthy forests actively store carbon through forest growth, resist of the pathogen and the outbreak of insect and recovery from damages such as forest fire [7].

2 Materials and Methode

The study was conducted in October 2016 in Protection Forest Register 25, Kelumbayan District, Tanggamus Regency. The data obtained using plot clusters based on the Forest Health Monitoring (FHM) method according to [8]-[9]. Each plot cluster (Figure 1.) consists of four plots. The location of the plot cluster was determined based on purposive sampling. Four plot clusters consist of two plot clusters in the primary forest area and two plot clusters in the secondary forest area.

The important value index (INP) and tree biomass were tree species, tree diameter, and tree height. Based on [10], the sampling of litter and understorey biomass was determined as follows: if the wet weight is more than 300 grams, then the used sample is 300 grams. If the wet weight obtained is less than 300 grams, then the sample used is 100 grams. If the wet weight obtained is less than 100 grams, the used sample is as much as that obtained.

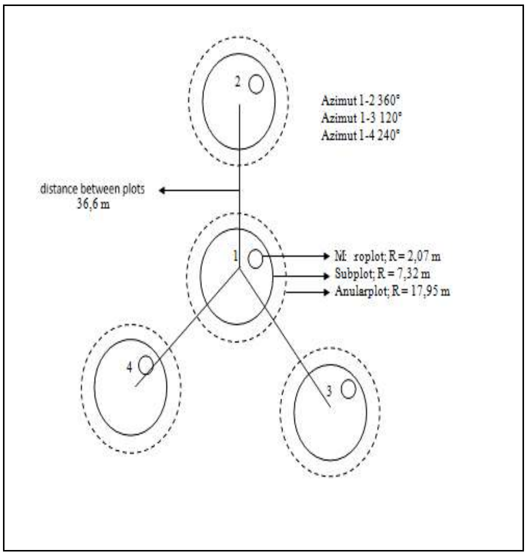

Figure 1 Cluster plot design

Source: [9]-[10]

Description: Annular plots for retrieval of tree biomass and Important Value Index (INP) data. Micro-plot for the collection of understorey and litter biomass data.

The Important Value Index (IVI) on vegetation can be calculated based on the Ministry of Environment Decree No. 201 year 2004 with the following equation:

$$K = \frac{\text{Individual number of a species}}{\text{Area of all sample plots}} \quad (1)$$

$$KR = \frac{\text{Density of a species}}{\text{Density of all species}} \text{ x } 100\% \quad (2)$$

$$F = \frac{\text{Number of plots a species found}}{\text{Number of all plots}} \quad (3)$$

$$FR = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \text{ x } 100\% \quad (4)$$

$$D = \frac{\text{Basal area of a species}}{\text{Area of all sample plots}} \quad (5)$$

$$DR = \frac{\text{Dominancy of a species}}{\text{Dominancy of all species}} \text{ x } 100\% \quad (6)$$

Based on the equation, the formula to calculate the species' IVI is:

$$IVI = RD + RF + RD \quad (7)$$

Description: D = Density, RD = Relative Density, F = Frequency, RF = Relative Frequency, D= Dominancy, RD = Relative Dominancy

The measurement of biomass in trees done by measuring the diameter at breast height and tree height then was analyzed using the general allometric equation proposed by [1], which is

$$W = 0,11 \text{ x } \rho \text{ x } D^{2,62} \quad (8)$$

Description:

W = biomass (kg)

ρ = wood density (g/cm3)

D = diameter at breast height (cm)

The obtained total tree biomass (kg) = DW1 + DW2 + ...+ DWn (9)

Description:

DW = Dry Weight

The formula for calculating biomass per unit area (tons/ha) as follows:

$$\textit{Total Biomass (kg)/Area } (m^2) \quad (10)$$

The measurements of litter and understorey biomass were carried out by weighing wet weight data then oven at a temperature of 800°C until the weight was constant. The sample was then weighed as dry weight. Both samples can be used to estimate biomass using the Biomass Expansion Factor formula [11].

$$\text{Total DW} = \frac{\text{DW of sub sample (gr)}}{\text{WW of sub sample (gr)}} \text{ x total WW} \quad (11)$$

Description:

DW = Dry Weight (gr)

WW = Wet Weight (gr)

After the biomass value was obtained, carbon calculation was carried out. According to [12], the carbon fraction from biomass is 0.50 (0.44 – 0.55), which means that 50% of the biomass is stored carbon, so a large amount of stored carbon can be calculated.

There are 3 health categories on Protected Forest Register 25, namely poor, medium, and good. These categories were obtained by calculating the threshold value of the carbon volume above the ground. The carbon volume threshold value above the ground was obtained based on the highest and lowest values of carbon volume calculation on each plot cluster.

3 Results and Discussion

3.1 Important Value Index in Protection Forest, Register 25

Important Value Index (IVI) is calculated to determine the importance of a plant species and its role in the community and the important values on tree and seedling levels of vegetation. The greater IVI value of species, the greater the level of dominance of the community and vice versa

[13]. In order to discover the relation between tree phase IVI and the amount carbon measured, the IVI calculation in the Protected Forest Register 25 was conducted only on tree phase.

Table 1 Results of tree phase Important Value Index calculations in Protection Forest Register 25

No	Tree species		Register 25			
	Local name	Latin name	Plot cluster 1 (%)	Plot cluster 2 (%)	Plot cluster 3 (%)	Plot cluster 4 (%)
1	Waru	*Hibiscus tiliaceus*	41,97	72,75	-	-
2	Dadap	*Erythrina variegata*	19,11	7,07	-	-
3	Medang	*Litsea sp.*	45,36	35,5	-	-
4	Cempaka	*Michelia alba*	35,70	-	-	-
5	Suren	*Toona sureni*	17,56	16,92	-	-
6	Mangir	*Ganophyllum falcatum*	9,66	-	-	-
7	Bayur	*Pterospermum javanicum*	46,27	52,23	-	-
8	Beringin	*Ficus benjamina*	18,54	12,72	-	-
9	Meranti	*Shorea sp.*	24,53	29,77	-	-
10	Gondang	*Ficus variegata*	25,16	7,07	-	-
11	Jaha	*Terminalia bellirica*	9,93	-	-	-
12	Sonokeling	*Dalbergia latifolia*	6,22	18,22	-	-
13	Durian	*Durio zibethinus*	-	-	127,85	120,67
14	Mangga	*Mangifera indica*	-	-	26,74	-
15	Melinjo	*Gnetum gnemon*	-	-	75,05	45,78
16	Cengkeh	*Syzygium aromaticum*	-	-	39,90	45,88
17	Jambu air	*Syzygium aqueum*	-	-	14,92	-
18	Petai	*Parkia speciosa*	-	-	15,54	87,67
Total			300	300	300	300

As presented in Table 1, bayur (*Pterospermum javanicum*) obtained the highest IVI on plot cluster 1 that is 46.27%. On plot cluster 2, the highest IVI obtained by waru (*Hibiscus tiliaceus*) with a value of 72.75%. On plot cluster 3 and 4, the highest IVI obtained by durian (*Durio zibethinus*) with a value of 127.85% and 120.67%, respectively. The highest IVI of all was obtained by durian (*Durio zibethinus*) on plot cluster 3 (127.85%), and the lowest obtained by sonokeling (*Dalbergia latifolia*) on plot cluster 1 (6.22%).

3.2 Measurement Results of Stored Carbon in Protected Forest, Register 25

The above ground biomass and carbon measurements in Protected Forest Register 25 were carried out in 4 plot clusters. Plot clusters 1 and 2 were located in the primary forest, while plot clusters 3 and 4 were located in the secondary forest.

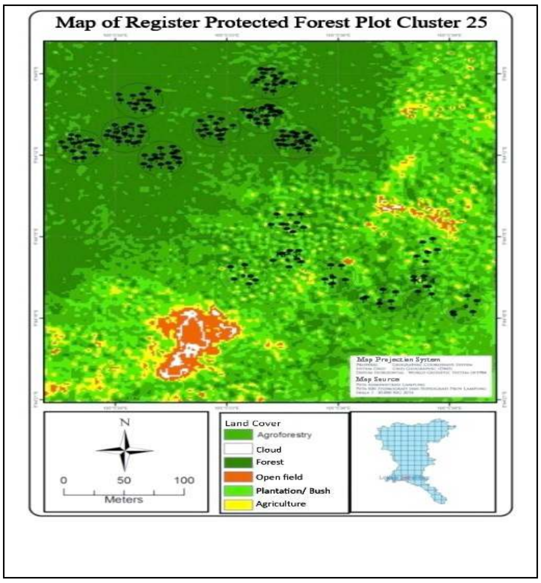

Figure 2 Carbon analysis plot clusters distribution map on Protected Forest, Register 25

Plot cluster 1 located in the primary forest of Protected Forest Register 25 and stored biomass of 3,484.49 tons/ha or carbon of 1,742.25 tons/ha, the largest due to its considerable amount of trees and diameters compared to other plot clusters. The number of trees in plot cluster 1 was 68 trees consisted of 12 tree species, namely waru (*Hibiscus tiliaceus*), dadap (*Erythrina variegata*), medang (*Litsea* sp.), cempaka (*Michelia* alba), suren (*Toona sureni*), mangir (*Ganophyllum falcatum*), bayur (*Pterospermum javanicum*), beringin (*Ficus benjamina*), meranti (*Shorea* sp.), gondang (*Ficus variegata*), jaha (*Terminalia bellirica*) and sonokeling (*Dalbergia latifolia*).

Plot cluster 2 contributed 3,176.44 tons/ha or 1,588.22 tons C/ha to the stand biomass carbon of Protected Forest Register 25. The number of trees in plot 2 cluster was 64 trees with 9 species of trees namely waru (*Hibiscus tiliaceus*), dadap (*Erythrina variegata*), medang (*Litsea* sp.), suren (Toona sureni), bayur (*Pterospermum javanicum*), beringin (*Ficus benjamina*), meranti (*Shorea* sp.), gondang (*Ficus variegata*) and sonokeling (*Dalbergia latifolia*).

Plot cluster 3 was located in the secondary forest with a contribution of the biomass of 422.14 tons/ha or carbon of 211.07 tons /ha. There were 29 individual trees of 9 species, namely durian (*Durio zibethinus*), mangga (*Mangifera indica*), melinjo (*Gnetum gnemon*), jambu air (*Syzygyum aqueum*), cengkeh (*Syzygium aromaticum*) and petai (*Parkia speciosa*).

Plot cluster 4 had the smallest stand carbon value compared to the other plot clusters due to its minor number and average tree diameter compared to other plot clusters. It contributed 416.35 tons/ha or carbon was 208.18 tons/ha of biomass. There were 24 trees in plot cluster 4, consisted of 4 species, namely durian (*Durio zibethinus*), petai (*Parkia speciosa*), melinjo (*Gnetum gnemon*), and cengkeh (*Syzygyum aromaticum*).

The amount of litter and understorey carbon in plot cluster 1 were 1.19 tons/ha and 0.66 tons/ha, respectively. Plot cluster 2 stored litter carbon by 0.81 tons/ha and understorey carbon by 0.61 tons/ha. The litter carbon of plot cluster 3 was 1.15 tons/ha while its understorey carbon was 0.55 tons/ha. Plot cluster 4-stored litter and understorey carbon with values of 1.08 tons/ha and 0.71 tons/ha, respectively.

3.3 The Analysis of Stored Carbon on Protected Forest, Register 25

The largest proportion of carbon storage on land is found in tree components or stands [10]. The four plot clusters were used for biomass measurements and to determine the values of carbon stored in the stands of Protected Forest Register 25. The said values are presented in Table 2.

Table 2 The amount of biomass and carbon stored in the stands of Protected Forest Register 25

No	Location	Biomass (ton/ha)	Stored Carbon (ton/ha)
1	Plot cluster 1	3,484.49	1,742.25
2	Plot cluster 2	3,176.44	1,588.22
3	Plot cluster 3	422.14	211.07
4	Plot cluster 4	416.35	208.18
Total		7,499.42	3,749.72
Average		1,874.86	937.43

Table 2 shows that the plot cluster 1 stored the largest biomass and carbon (46.46%) with a biomass value of 3,484.49 tons/ha or 1,742.25 tons C/ha due to its largest average diameter compared to other cluster plots. In accordance with [14], the greater the diameter of a tree, the greater the biomass contained due to its ability to absorb more CO2. Plants absorb CO2 from the air and convert it into organic compounds through photosynthesis.

The stored biomass and carbon in litter and understorey in Protected Forest Register 25 were measured by taking samples on micro-plots in each cluster plot. Litter is defined as dead organic matter that is on the forest floor [15]. The results of measurements of stored biomass and carbon in litter and understorey in Protected Forest Register 25 are presented in Table 3.

Table 3 The amount of biomass and carbon stored in the litter and understorey of Protected Forest Register 25

No	Location	Litter		Understorey	
		Biomass (ton/ha)	Stored Carbon (ton/ha)	Biomass (ton/ha)	Stored Carbon (ton/ha)
1	Plot cluster 1	2.38	1.19	1.31	0.66
2	Plot cluster 2	1.61	0.81	1.21	0.61
3	Plot cluster 3	2.30	1.15	1.10	0.55
4	Plot cluster 4	2.16	1.08	1.41	0.71
Total		8.45	4.23	5.03	2.53
Average		2.11	1.06	1.26	0.63

Litter and understorey biomass and carbon are influenced by the vegetation conditions where they grow. This is as stated by [16], that the biomass and carbon content of understorey is influenced by the composition of understorey vegetation. Similarly, the content of biomass and carbon in the litter is influenced by its constituent components, for example, rotten wood, leaves, and twigs.

The results of measurements of stored carbon from each cluster plot in Protected Forest Registered 25 are in Table 4.

Table 4 Stored carbon on each plot cluster of Protected Forest Register 25

No	Location	C stands (ton/ha)	C Litter (ton/ha)	C Understorey (ton/ha)	Total C/Cluster (ton/ha)	Persentage (%)
1	Plot cluster 1	1,742.25	1.19	0.66	1,744.10	46.43
2	Plot cluster 2	1,588.22	0.81	0.61	1,589.64	42.32
3	Plot cluster 3	211.07	1.15	0.55	212.77	5.66
4	Plot cluster 4	208.18	1.08	0.71	209.97	5.59
Total		3,749.72	4.23	2.53	3,756.48	100
Average		937.43	1.06	0.63	939.12	

Table 4 shows that plot cluster 1 contributed the largest stored carbon in the Protection Forest Register 25, that is 46.43% or 1,744.10 tons C/ha. Cluster 1 also has the largest number and type of trees compared to other plot clusters according to the IVI calculations that have been carried out. It showed the correlation between the IVI value and carbon in vegetation. Greater IVI value will increase carbon stored. According to [17] stated that there is a significant positive relationship between IVI and biomass or carbon, which means an increase in IVI is proportional to biomass or carbon. The diameter of trees used to calculate biomass or carbon and dominance in IVI also affected this, so that the amount of biomass or carbon indirectly correlates with the dominance of the tree species.

Compared with the similar studies, the storage of above-ground carbon in Protected Forest Register 25 was greater than that of Setanjo Protection Forest at Riau. According to [18], Setanjo Protection Forest stores 223.18 tons/ha carbon. The agroforestry area of Register 39 *Datar Setuju* at the Protected Forest Management Area Batutegi stored 178.24 tons/ha carbon. In conclusion, Register 25 was more carbon saving than the other regions.

The better ability of the Protection Forest Register 25 to store carbon showed that it has good ecological functions. According to [19], if a land cover has a good ecological function, it has a better ability to absorb or sink carbon.

3.4 The Determination of Protected Forest Register 25's Health Category

The carbon volume threshold value was used to determine the health category of Protection Forest Register 25. Based on the highest and the lowest values from the calculation of the above-ground carbon volume that has been carried out in all cluster plots, the health threshold value of Protection Forest Register 25 as follows:

Table 5 The health threshold value of Protected Forest Register 25

Threshold Value	Health Category of Protected Forest Register 25
209.97 – 721.35	Poor
721.36 – 1,232.74	Medium
1,232.75 – 1,744.13	Good

Based on the threshold values in Table 5, plot cluster 1 and 2 which stores 1,744.10 tons/ha and 1,589.64 tons/ha carbon, respectively, are included in the good category. Both clusters store the largest carbon compared to plot clusters 3 and 4. Due to their location on the primary forest which dominated by forestry plants, plot cluster 1 and 2 have the largest carbon deposit on their tree stands.

Plot cluster 3 and 4 stores 212.77 tons/ha and 209.97 tons/ha carbon, respectively, and classified into the poor category because their ability to store carbon was less than plot cluster 1 and 2. Both cluster 3 and 4 plots were located in the secondary forests dominated by Multi-Purpose Tree species (MPTs) and plantation crops so that the carbon stored in the two cluster plots was smaller than the plot clusters dominated by forestry plants.

4 Conclusion

Based on the analysis, the above ground carbon can be used as a health indicator for Protection Forest Register 25 in the categories of poor, medium and good. Plot cluster 1 and 2 categorized as good (1,232.75 tons C/ha – 1,744.13 tons C/ha). Plot cluster 3 and 4 categorized as poor (209.97 tons C/ha - 721.35 tons C/ha).

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