JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2023, 24(1), 97–106
https://doi.org/10.12911/22998993/156056
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Received: 2022.10.05
Accepted: 2022.11.09
Published: 2022.12.01

Contribution of Hampangen Education Forest Central in Kalimantan to Climate Change Mitigation – An Above Ground Biomass Assessment

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ABSTRACT

Hampangen Education Forest (HEF) has great potential in terms of carbon stock, biodiversity, and contribution to the local community's livelihood. In the future, it is planned to develop its role in climate change mitigation; thus, valid and updated information regarding climate regulation services are required. The purpose of this study was to assess the above ground biomass (AGB) at different canopy densities of swamp secondary forest in (HEF) and estimated the total AGB stored in this area. The research was carried out from April 2022 until July 2022. The data collected included tree diameter at breast height (DBH), tree total height, the weight of litter, and understorey vegetation. All the information was collected using two types of observation plots (400 m^2 and 0.25 m^2) and AGB was calculated using allometric equations. This research found that the average AGB at sparse, medium, and dense canopy cover was 70.46 $Mg.ha^{-1}$, 80.94 $Mg.ha^{-1}$, and 145.03 $Mg.ha^{-1}$, respectively. The total AGB stored in HEF was 367,180.08 Mg (tonnes) and equivalent to above-ground carbon stock of 172,574.64 Mg carbon. The finding of this research suggests that HEF needs conservation strategies to improve its carbon stock and conserve biodiversity.

Keywords: climate change, above ground biomass, Hampangen education forest, Central Kalimantan.

INTRODUCTION

Indonesia has a central role in climate change mitigation for two main reasons: (1) Indonesia is one of the largest emitters in the world and (2) Indonesia has great potential to mitigate climate change by conserving its natural forest and reducing deforestation, forest degradation and forest fire (UNSD, 2016). Annual emissions from Indonesia indicated an increasing trend, in the period 2012–2017 CO_2 emission raised by 18%. Most of this emission is supplied by anthropogenic activities including forest conversion for agriculture expansion, peatland drainage, and forest fire (Hamilton and Friess, 2018; IPCC, 2014; Margono et al., 2014, Tata et al., 2014; Turestky et al., 2015; Wijedasa et al., 2018). For example, peatland conversion to palm oil (*Elaeis guinensis*) plantation generates continuous GHGs emissions. Drainage of peat caused to change in the physical characteristic and followed by subsidence and continuous release of CO_2 and other gases (Miettinen et al., 2016). In addition, timber extraction both by companies and local communities reduces the capability of the forests to absorb and store the atmospheric CO_2 (Gibbs et al., 2010; Lund, 2009). On the other hand, conserving high carbon stock ecosystems such as peatland forests, contribute significantly to reducing climate change acceleration. Above-ground carbon stock on peat forest projected 230 ± 66 Mg·ha^{-1} and peat organic matter contains 2425 ± 726 Mg·ha^{-1} (Andriesse JP, 1988). It was estimated that the peatland forests in Indonesia stored 13.6 Gt to 57.4 Gt of carbon (Page, Rieley, and Banks, 2011; Warren et al., 2017)

Beside the significant role on climate change mitigation, tropical forest conservation also benefit socio-economic for local society, maintaining water quality and biodiversity preservation (Dommain et al., 2016; Monkkonen, et al., 2014; Stibig et al., 2014; Thornton, 2017). Forest provide various products and services that are necessary for livelihood and basic needs of local communities lived around to forest. Various non-timber forest products, such as honey, medicinal plants, latex, fruits and fabric support community daily need and generate income (Rist et al., 2012). Borneo and Sumatera island are famous as biodiversity hotspot (Myers et al., 2000), habitat for numerous flora and fauna. Study by Anderson (1963), recorded approximately 927 vegetation species including tree, fern, orchid and shrubs exist in peat swamp forest. Due to specific characteristic of the habitat, many of tree species in swamp forest are endemic (Yule, 2010).

Managing tropical forests to meet various necessities is challenging. For example, emission reduction programs are also required to assure biodiversity conservation and take into account the rights of indigenous people. Reduction of emissions from deforestation and degradation (REDD) offers a solution to this challenge involving a mechanism which could be funded from the global population and support climate change mitigation programs in Indonesia (Goldstein et al., 2015; Simula, 2010). In the past decade, Indonesia has been showing a good performance in this program, especially in conserving forest and peatland (Agung et al., 2014; Busch et al., 2015). REDD allows the Indonesia government to align the reduction emission program with biodiversity conservation and local community development (Herold and Skutsch, 2009; UNFCC, 2009).

HEF is located in one region of KPHP Katingan Hulu. A previous study in this area found that HEF has the potential for medicinal plants. This study found 19 medicinal species with a diversity and evenness index of 2.62 and 0.89, respectively. The famous medicinal plants from this forest include Akar Kuning (*Fatoa spilosa*), Akar kalaawit (*Uncaria cordata*), and sintuk (*Cinnamomun partonoxyon*) (Sosilawaty, 2020). Another research conducted by Rotinsulu et al., 2021 found 47 species of tree from all growth stages and calculated above-ground biomass ranging between 152,69 Mg·ha^{-1} and 122.93 Mg·ha^{-1}. There is no study yet related to the biomass stock in various forest cover densities and estimated all biomass deposited in HEF.

In the future, it is planned to develop the role of HEF in climate change mitigation. This study is the first step of the Hampangen development strategic plan, collecting basic information regarding ecological, economic, and social aspects. The research assessing biomass and carbon stock is essential since they could inform how the system could prevent CO_2 release and preserve biodiversity at the same time (Aryapratama and Pauliuk, 2019). In addition, the information regarding CO_2 emission, carbon sequestration, and how intervention programs could improve carbon stock is required for implementing REDD (Herold and Skutsch, 2009). The purpose of this study was to assess the above ground biomass (AGB) at different canopy densities of swamp secondary forest in HEF and estimated the total AGB stored in this area.

METHOD

Research site

The present study carried out in HEF in Central Kalimantan Indonesia. HEF is located at 113° 28′ 23.40″ East to 113 ° 34 ′ 22.09 ″ East and 1° 49′ 52.33″ South to 1° 54′ 15.53″ South, covering an area of 5000 hectares. It is situated near to highway road, this location can be reached about 1.5 hours from Palangka Raya, the capital city of Central Kalimantan. Figure 1 present the map of Hampangen education forest. The legal status of Hampangen education forest obtained from Ministry of Forestry Degree number 311 / Kpts-2/1993. Before, it was managed by Palangka Raya University, this area governed by forest concession company, PT. Gelora Dayak Besar. The company harvest timber such as meranti (*Shorea johorensis*), ulin (*Eusideroxylon zwageri*), Belangiran Shorea balangeran, and madang (*Swietenia macrophylla*) (Sosilawati, 2020).

The HEF area is included in the secondary peat swamp forest with peat depths ranging from 3-4 meters. The lowest monthly rainfall occurs in August (80 mm) and the highest in January (370

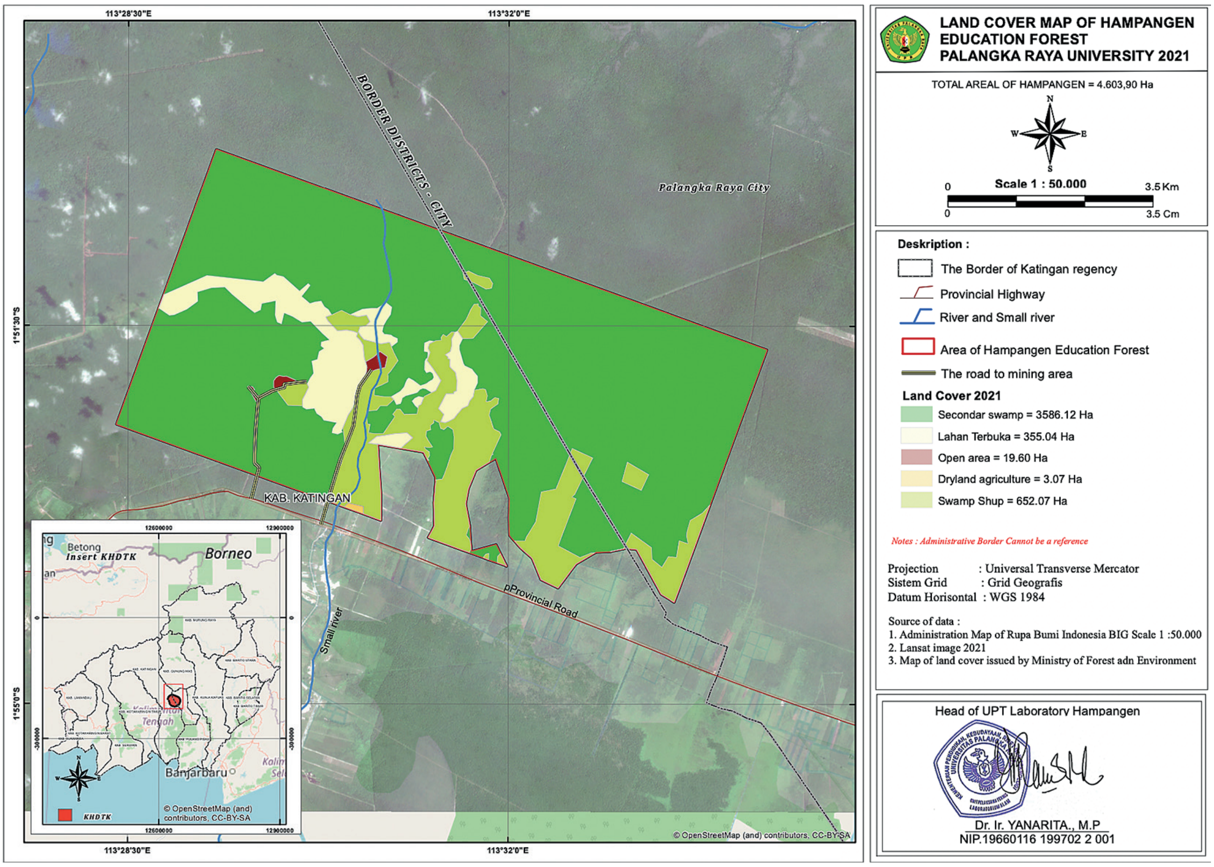

Figure 1. Map of Hampangen Education Forest

mm). The average annual rainfall reaches 2,800 mm. The part of the HEF that has a low elevation will be inundated in the rainy season and this is a factor supporting the formation of peat (Shiodera et al., 2012).

The nearest settlements around the HEF are the Bukit Batu and Luwuk Kanan villages. The residents in these villages mostly come from Dayak ethnic group and generate their income from managing traditional rubber plantations, planting paddy with a shifting cultivation system, fishing, and collecting forest products. Rubber plantations managed by the locals are traditional rubber which is low in productivity. Besides rubber plantations, fishing also supports the livelihood of the locals. Rivers, lakes, and swamps around this area provide abundant fish such as snakehead fish, patin, baung, and seluang. The income they obtained from fishing could cover their daily expenses. For the last decades, there has been a trend in the community to build a tower with a height ranging from 10 to 20 meters. By building this tower they hope that the swallow bird will nest in that building and farmers could harvest and sell the swallow nest. The price of a Kg swallow nest is relatively high, with an average IDR. 1.5 million. Unfortunately, farmer often collect the material for the tower from the forest around the village including HEF. For the nest tower, they prefer soft wood with a diameter of more than 40 cm, for example, pulai, alau, and kapur naga.

Data collection and analysis

The research was carried out from April 2022 until July 2022. On the basis of satellite image analysis HEF is classified into swamp secondary forest, swamp shrub, mining, dry agriculture, and open area. The study focused on swamp secondary forest that is considered to have higher carbon stock. On the basis of the density of canopy cover, swamp secondary forests were classified into three categories: sparse canopy cover, medium canopy cover, and dense canopy cover. This research adopted a 400 m^2 square measurement plot to measure the trees with a diameter at breast high (DBH) of more than 5 cm and a smaller plot (0.25 m^2) to measure understorey vegetation and litter. Four small plots were arranged within a 400 m^2 plot. In each forest canopy category, three 400

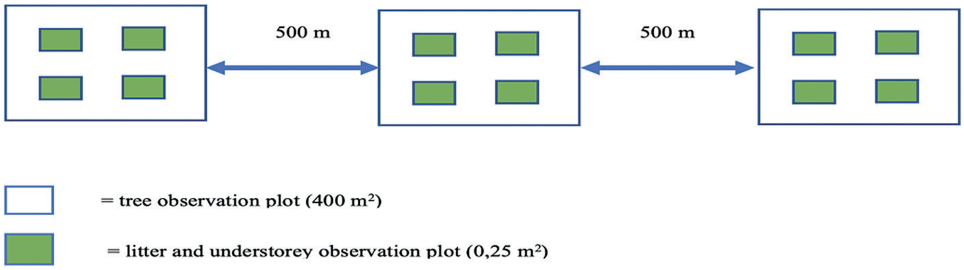

Figure 2. The arrangement of measurement plots

m^2 plots and 12 0.25 m^2 plots we placed. The distance between plots was 500 m. Figure 2 presents the arrangement of measurement plots.

The information collected in 400 m^2 plot included the local name of the tree, DBH in meters and total height also in meters. Meanwhile, the data generated from 0.25 m^2 comprised the fresh weight understorey vegetation and the fresh weight of litter. The data were collected using destructive procedure. First, all understorey vegetation within the plot were cut and weighed; then, 100 grams were collected as a sample for drying up in the oven. The same procedure was applied for litter.

The samples obtained from the forest were then dried in the oven with the temperature around 80 °C until constant weight was achieved. After constant weight was achieved, the sample was then scaled up to find dry biomass weight. The total understorey biomass per ha was calculated using equation:

$$TU = \frac{DSU \times FU}{WU} \times (10000/0.25) \times 1.10^{-6} \quad (1)$$

where: TU – total understorey biomass (Mg·ha^{-1});
DSU – biomass of dry sample (gram);
FU – weight of fresh understorey (gram).

Total litter biomass calculated employing following equation:

$$TL = \frac{DSL \times FL}{WL} \times (10000/0.25) \times 1.10^{-6} \quad (2)$$

where: TL – total litter biomass (Mg·ha^{-1});
DSL – biomass of litter dry sample (gram);
FL – weight of fresh litter (gram).

Biomass of tree was calculated using allometric equation developed by Basuki et al., (2009)

$$\mathrm{AGB} = 0.106\, D^{2.03} H^{0.542} \quad (3)$$

where: AGB – above ground biomass (kg);
D – DBH (cm);
H – total height (m).

RESULT

In total, 37 species of the tree were identified across all plots. The species with the highest number was tumih (*Combretocarpus rotundatus*). At the second and third places were Gerunggang (*Cratoxylum sumatranum*) and Tabulus. Table 1 shows that there is contra in terms of the number of trees, some species can be found abundantly and in contrast, some spiciest only exist for a single tree for example malam-malam (*Diospyros bantamemsis*), ehang (Diospyros Siamang Bakh) and kayu tanah (*Horsfieldiacrassifolia cf.*).

Sparse canopy cover

The tree density in this classification varied distinctly between plots, ranging from 300 trees·ha^{-1} in plot 1 to 575 trees·ha^{-1} in plot 3. The tree density also reflects the biomass stored in the tree. The tree biomass ranged from 15.41 Mg·ha^{-1} in plot 1 to 110.08 Mg·ha^{-1}. Besides being related to tree density, the tree biomass also influences the size of the tree. The average DBH in plot one was 10.41 cm and in plots, two and three were 16.50 cm and 16.65 respectively.

The understorey vegetation in the observation plots consisted of saplings or seedlings of trees, shrubs, and several types of ferns and forest taro. The average amount of understorey biomass is 3.3 Mg·ha^{-1} which is equivalent to a carbon content of 1.6 Mg·ha^{-1}. The amount of understorey biomass had a small variation between plots with a standard deviation of 0.24.

The litter in this study is a pile of dead tree leaves and twigs on the ground. The litter biomass in the sparse cover secondary forest is 8.08 Mg·ha^{-1} or the equivalent of 3.78 Mg·ha^{-1} carbon. Consistent with understorey vegetation, litter biomass did not vary widely between plots, the standard deviation between plots was 0.15. The

Table 1. List of tree species found at all measurement plots

No	Local name	Scientific name	Number of tree
1	Tumih	*Combretocarpus rotundatus*	104
2	Gerunggang	*Cratoxylum sumatranum*	85
3	Tabulus	NA	36
4	Meranti	*Shorea sp.*	32
5	Gula-Gula	*Calophyllum macrocarpum*	24
6	Pisang-Pisang	*Mezzetia leptopoda*	22
7	Jambu	*Syzigium sp*	18
8	Jambu-Jambuan	*Syzigium sp*	18
9	Rambutan	*Xerospermum sp.*	14
10	Terantang	*Campnosperma coriaceum*	7
11	Mandrahan	*Gymnacranthera sp*	6
12	Mandanahan	*Gymnacranthera sp*	6
13	Gelam Merah	*Syzygium lineatum*	6
14	Mahalilis	*Artocarpus sp*	5
15	Manggis Hutan	*Garcinia cf.bancana*	4
16	Jambu Merah	*Syzigium sp*	4
17	Panut	*Calophyllum sp*	4
18	Tutup Kabali	*Diospyros pseudomalabarica*	4
19	Marlibu	*Dactylocladus stenosteachys*	4
20	Tanggaring Banjar	*Castanopsis sp*	3
21	Pantung	*Dyera lowii*	2
22	Kemuning	*Xanthophyllum ellipticum*	2
23	Sagagulang	*Blumeodendron sp*	2
24	Nyatoh	*Madhuca sp*	2
25	Bintangur	*Calophyllum hosei*	2
26	Tambuning	NA	2
27	Jambu Putih	*Syzigium sp*	2
28	Punah	*Calophyllum sp*	2
29	Rambutan Hutan	*Xerospermum sp.*	2
30	Punak	*Tetrameristra glabra*	2
31	Asam-Asam	*Antidesma* sp.	2
32	Malam-Malam	*Diospyros bantamemsis*	2
33	Ehang	Diospyros Siamang Bakh	1
34	Piais	NA	1
35	Badaru	Cantleya corniculata	1
36	Kayu Tanah	*Horsfieldiacrassifolia cf.*	1
37	Belanti		1

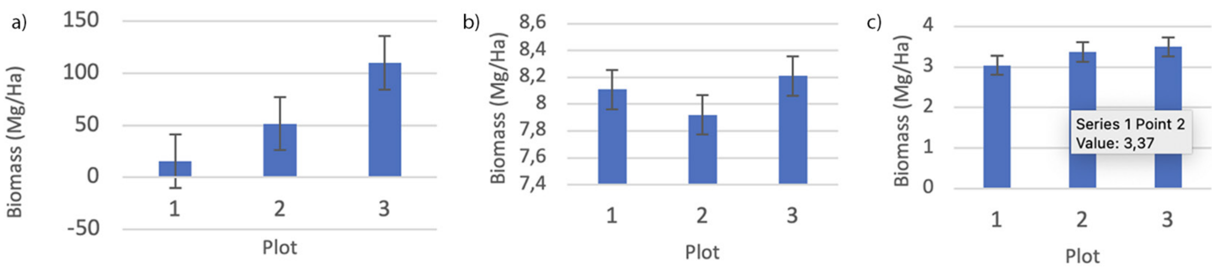

Figure 3. Biomass of tree, litter and understory in sparse canopy cover

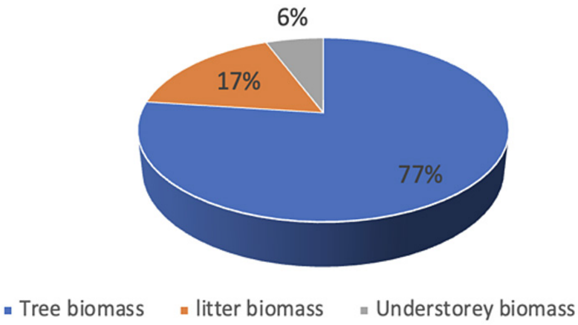

Figure 4. Proportion of AGB in sparse canopy cover

biomass of tree, litter and understory vegetation are presented at Figure 3.

The average total above-ground biomass in sparse canopy cover was 70.46 Mg·ha^{-1} or equivalent to a carbon content of 33.12 Mg·ha^{-1}. Above ground, biomass consists of tree biomass, understorey biomass, and litter biomass. The total biomass in the measurement plots was uneven, the smallest was 26.56 Mg·ha^{-1} and the largest was 121.79 Mg·ha^{-1}. The largest proportion of the total aboveground biomass was contributed by trees, while litter biomass contributed 17% and understory had the smallest proportion accounting for 6% (see Figure 4).

Medium canopy cover

On the basis of field measurements, the medium-cover secondary forest has an average of tree density 658.33 trees·ha^{-1}. Tree density on the medium cover was relatively homogeneous with a standard deviation of 62.91. The vegetation in the measurement plots was dominated by tumih (*Combretocarpus rotundatus)*, gerunggang (*Cratoxylum sumatranum*), and pisang-pisang (*Mezzetia leptopoda)*. This area experienced a major fire in 1998 and became an open area. The forest then experienced succession and formed a secondary forest dominated by pioneer species after fires.

The amount of biomass stored in trees was an average of 69.23 Mg·ha^{-1} which was equivalent to a carbon content of 32.54 Mg·ha^{-1}. The largest biomass content was in plot 2, which was 80.79 Mg·ha^{-1}, and the smallest in plot 3 58.12 Mg·ha^{-1}. The fluctuations in tree biomass in the three plots were relatively small, with a standard deviation of 11.34.

In general, litter biomass was smaller than understory biomass; this indicates that the number of seedlings and other understory plants is higher than in other locations. The average litter biomass was 5.15 Mg·ha^{-1} with a standard deviation of 0.58 Mg·ha^{-1}. There was a significant difference in understory biomass in each plot. The average understory biomass was 6.58 Mg·ha^{-1} or equivalent to a carbon content of 3.09 Mg·ha^{-1}. The largest understory biomass content in plot 2 was 13.08 Mg·ha^{-1} and the smallest in plot 1 was 2.88 Mg·ha^{-1}. Detail biomass in each component can be seen at Figure 5.

The measurement results on the observation plot showed that the average aboveground biomass in the medium-cover secondary forest was 80.94 Mg·ha^{-1} or equivalent to a carbon content of 38.04 Mg·ha^{-1}. The standard deviation of total biomass in the secondary forest of medium cover is smaller than that of sparse cover; this

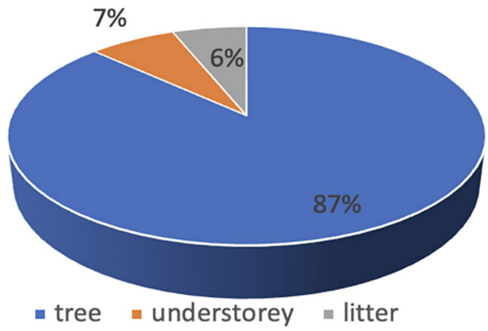

Figure 6. Proportion of AGB in medium canopy cover

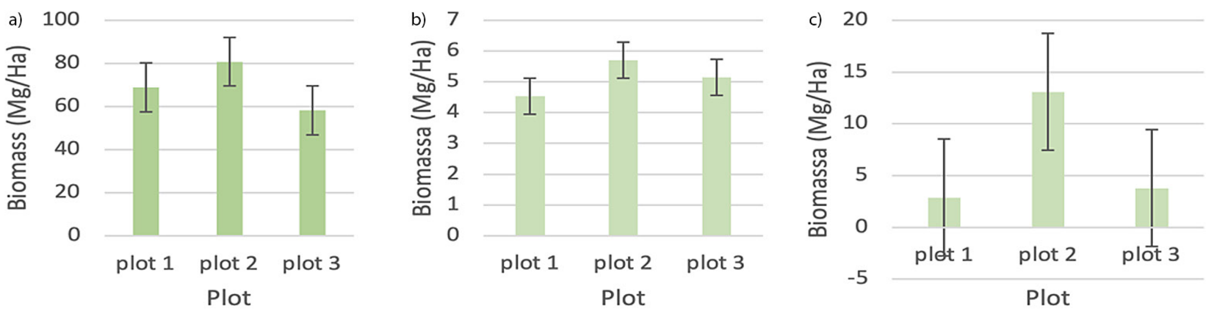

Figure 5. Biomass of (a) tree, (b) litter and (c) understorey in medium canopy cover

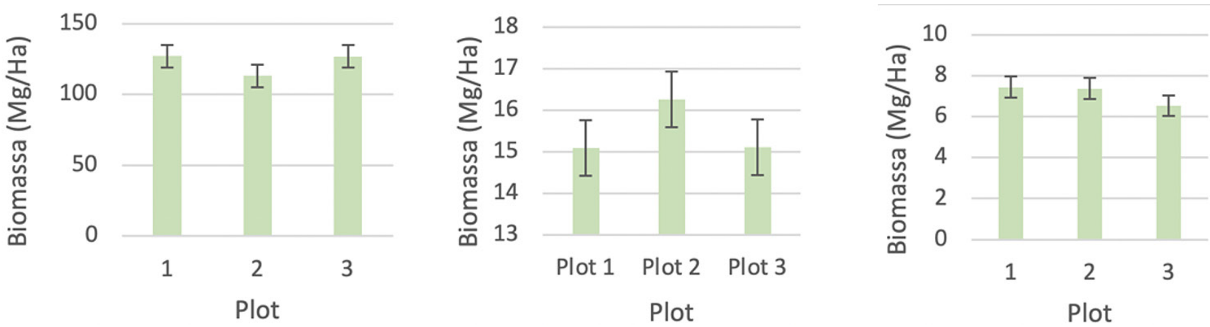

Figure 7. Biomass of (a) tree, (b) litter and (c) understorey in dense canopy cover

indicates that the tree stands at this location are more stable. Figure 6 depicts the proportion of AGB in each component. Of the total aboveground biomass, the majority added by tree biomass while litter and understorey biomass gave 6% and 7%, respectively.

Dense canopy cover

Dense canopy cover has higher tree density than sparse and medium cover secondary forest. The average tree density reached 875 trees·ha^{-1}. The difference in tree density between plots in this area was small, the standard value was 50. This indicated that the vegetation community in this location was reasonably stable.

Trees play a very important role in forest carbon sequestration, because the largest proportion of forest carbon is stored in trees. The results of the analysis showed that the average biomass of trees in dense cover secondary forest was 122.43 Mg·ha^{-1}. This quantity was equivalent to a carbon content of 57.54 Mg·ha^{-1}. As with tree density, the amount of carbon content in trees has relatively small fluctuations between plots.

The average understorey biomass in dense canopy cover was 7.12 Mg·ha^{-1} which was equivalent to a carbon content of 3.35 Mg·ha^{-1}. In turn, litter biomass was higher than understorey biomass. Litter biomass ranged from 15 Mg·ha^{-1} to 16 Mg·ha^{-1}. Consistent with trends in understorey and tree biomass, litter biomass also did not fluctuate considerable between plots. Figure 7 shows the average AGB in each component of AGB.

The average aboveground biomass is 145.03 Mg·ha^{-1} which is equivalent to 68.16 Mg·ha^{-1} carbon. The aboveground biomass in the dense canopy cover was relatively stable; there were no large fluctuations between plots. Considering the percentage of each component to total above-ground biomass, the tree was the greatest contributor.

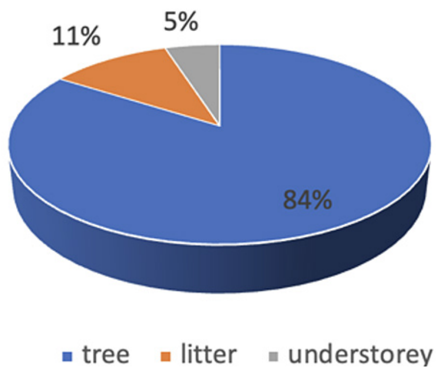

Figure 8. Proportion of AGB in dense canopy cover

While litter that consists of dead leaves, branches, and twigs was calculated at 11%, and the smallest proportion was attributed to understorey biomass. Proportion of AGB is presented in Figure 8.

Total biomass and carbon stock in Hampangen Education Forest (HEF)

The total area of KHDTK Hampangen is 4615.9 ha and based on land cover analysis, it was classified into 5 criteria, namely secondary swamp forest, swamp scrub, open land, mining area, and dry agriculture. This research revealed that the average AGB across secondary forests

Table 2. AGB in each land cover criteria

Land cover criteria	(Ha)	AGB (Mg/Ha)	Total AGB (Mg)
Swamp secondary forest	3586.12	98.81	354344.5172
Open area	355.04	0	0
Mining area	19.6	0	0
Dryland agriculture	3.07	64.64	198.4448
Swamp shrub	652.07	19.38	12637.1166
Total	4615.9		367180.0786

was 98.81 Mg·ha^{-1}, AGB from other land cover used the value from Ministry of Forestry and Environment, as presented in Table 2.

By accumulated AGB in each land cover criteria, the AGB in the Hampangen area was 367,180.08 Mg. This figure is equivalent to above-ground carbon stock of 172,574.64 Mg Carbon. From this data, it can be calculated that the amount of CO_2 absorbed and stored in the forest is 567,770.57 Mg.

DISCUSSION

The AGB across swamp secondary forests are varied, corresponding to the density of forest cover. The spare canopy cover had the lower AGB, 70.46 Mg·ha^{-1}, while the medium canopy cover saved 80.94 Mg·ha^{-1}and the highest AGB owned by the Dense canopy cover was 145.03 Mg·ha^{-1}. The differences between AGB in HEF were influenced by the forest fire event and the illegal logging by local communities. Great fire events occurred in 1997, 2015, and 2019. The 1997 fires event swiped almost all HEF area, except a small portion on the north side. The forest fire that occurred in 2015 burned almost half the area of HEF and the 2019 fire mostly took place in the shrub area.

The sparse and medium canopy cover experienced forest fire in 1997 and 2015 and the dense canopy cover only experienced forest fire in 1997. The frequency of forest fire events may be the factor influencing the differences in AGB at those three canopy densities. Another factor attributed to AGB is illegal longing conducted by communities around the HEF. Usually, communities are looking for good quality timber, such as Meranti (*Shorea*) and Belangiran (*Shorea balangeran*) as the main construction material for housing. The trees selected for this purpose are the trees with a diameter of more than 40 cm, which allows them to make wood boards. Besides, small trees with a diameter of less than 10 cm are preferred as supporting material in road construction or building construction.

Fire and illegal logging were the main factors that shaped the forest structure and biodiversity. Open areas and shrubs in HEF were the product of repeated fire and intense logging activities. The process of succession is sometimes disturbed or slowed down by some fire event. The natural regeneration of vegetation that starts to grow had vanished by the fire. This forced nature to restart the succession from the beginning. Sometimes, due to severe disturbance, the forest lost its capability to recover and resulting in open areas or shrubs.

The result of this study shows that the swamp secondary forests in HEF can regrowth and rebuild their biomass accumulation. After the fire event, the vegetation communities are dominated by pioneer species such as *Combretocarpus rotundus*. This finding is consistent with the study by Hoskilo et al., (2008). They found that in Block C Eks Mega Rice Project, pioneer species such as tumih (*Combretocarpus rotundus*), gerunggang (*Cratoxylon arborescens* (*Vahl.*) *Blume*), and dominated vegetation species after the fire event. The vegetation at the forest edge varies, mixed between pioneer species and vegetation from remaining forest, such as *Cratoxylon spp*., *Litsea spp*, and *shore spp*. According to Shiodera et al., (2012), *Combretocarpus rotundus* become the dominant pioneer species because this species can produce flowers and seeds abundantly all year long. In addition, the seed of this species has a wing that allows the seed spread to a broader area and also reinforces the capability of this seed to survive in the flood.

The AGB calculated by this research is lower compared with other research on the same forest type. The AGB from this research ranged from 70.46 Mg·ha^{-1} to 145.03 Mg·ha^{-1}, while Johanna et al. (2021) found that AGB at HEF ranged from 122.93 to 152.69 Mg·ha^{-1}. Afentina et al. (2022) in their research at adjacent forest at the north and east of HEF found the above-ground carbon was 73.55 Mg·ha^{-1} to 229.05 Mg·ha^{-1}. The lower AGB in this research may cause by the intensive logging activity during the one-year gap.

Regarding the management and conservation of HEF in the future, the result of this research could inform the decision maker that public awareness and law enforcement should implement. The logging activity by local communities has the potential to reduce the biodiversity and AGB of the forest. It is important to develop alternative livelihood for the locals through social forestry program. The social forestry program could embrace local communities to manage HEF. Alternative livelihoods, such as agroforestry or apiculture or agrosilvofisheries could become solutions to provide alternative income and reduce the pressure on HEF.

Regarding forest fire, the management of HEF could establish a community-based fire brigade in Indonesia, well-known as Masyarakat

Peduli Api (MPA). Management of HED in collaboration with the Forest and environment agency could train the MPA to prevent and control a forest fire. Fire prevention programs consist of public awareness programs, building deep well as water sources to distinguish fires, patrolling around HEF during the long dry season, and preparing all the equipment required for firefighting. Increasing public awareness can be conducted by installing warning signs in the fire prone area, for example near dry grassland and near dry agriculture region. Public awareness is the most crucial strategy since the main cause of forest fire in Central Kalimantan is anthropogenic activities including land clearing using fire or unintended fire caused by a cigarette.

AGB in HEF can be increased by conducting a replanting program. This research indicates that some areas of HEF can restock and build AGB through natural succession. However, some areas required human intervention to recover. The area such as shrubs and open areas required rehabilitation strategies that incorporated ecological condition improvement, forest fire prevention, and revegetation program. The right technique for peatland silviculture could improve the success probability of the revegetation program, for example, the right timing of planting, endemic species that could grow well on degraded peat, and hydrological treatment to maintain the water table.

CONCLUSIONS

This study found that AGB at swamp secondary forests was varied corresponding to the density of the canopy. The average AGB at swamp secondary forest was 98.81 $Mg \cdot ha^{-1}$and the total AGB of HEF was estimated at 367,180.08 Mg equivalent to the capacity to absorb CO_2 up to 567,770.57 Mg.

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