Contribution of Community Forest of Banyumas Regency on CO2 Absorption

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Abstract. A study on the absorption of carbon dioxide (CO_2) in the plant was conducted at low land and private highland forest. The purpose of this study was to get plant species with high CO_2 absorption in both lowland and upland of the private forest. The study used a survey method. The location was grouped into two strata, namely lowland and highland of the private forest. The sample of composition of the private forest vegetation at both lowland and highlands location was carried out by using quadrat 10 m x 10 m. The capacity of the plant CO_2 absorption was analyzed through the mass of carbohydrates. The results showed that there are 27 species of plants that consistently composed at both strata of private forest. These species consist of both trees, and crops with the number of species were 21 and 6 species, respectively. Species of trees that have a high absorption of CO_2 are *Tectona grandis*, *Neolamarckia cadamba, Havea brasiliensis, Coffeea robusta, Gmelina arborea, Cocos nucifera, Mangifera indica, Hibiscus macrophyllus, Canna edulis, Vigna sinensis, Zea mays*, and *Calocasia esculenta*. The results of this study can be used as a basis for preparing a sustainable private forest pattern-based on the high absorption of CO_2.

1. Introduction

The community forest development, in general, has not provided optimum ecological and environmental benefits. The existing community forest from an environmental perspective has not been able to balance CO_2 absorption with the amount of CO_2 emissions that increase continuously due to the increase of human activities. The low environmental and ecological benefits of community forests were presumably caused by the simple management conducted by farmers [1]. The farmers, in general, have not made a suitable arrangement plant structure and composition in the community forests [2]. The tree species selected were solely based on market demand with the considerable high selling prices, while wood crop and tree growth speed have not been considered.

Therefore the community forests diversity index, vegetation structure, and productivity were very low. Two studies found that the plant diversity index of the forests varies from 1.07 to 2.17. This condition shows a low plant diversity composing community forests so that the ecosystems tend to be unstable when a disturbance occurs [3, 4]. Likewise, with its vegetation structure such as plants age and height, the average plant height of community forests consists only of two layers. The first is trees with a similar height, and the second is annual plants [2]. Based on the diversity index and the tree height, community forests tend to be of the same age, so if the crop cycle has been achieved, there will be mass land clearance. As a result, the balance of the economic, environmental, and ecological benefits of community forest ecosystems are not sustainable. After logging, farmers will not return to the community forest production for a relatively long time. In the other scenario, if there are rains following the logging, the community forest will experience runoff and erosion, and the most disturbing there will be deforestation and even the cessation of CO_2 absorption while the emissions continue and increase.

Based on the above explanation, it is necessary to research the model of sustainable community forests capable of providing high ecological and economic benefits. An expected model of the sustainable community forest can be achieved through a series of studies. It should start with the search of plant species having high carbon conversion, water-absorption to reduce surface runoff and erosion, high production, and adaptation to highland environmental conditions. This consideration is that the higher the plant's carbon absorption, the higher the process of photosynthesis, which will eventually have a faster growth rate and result in high productivity. Therefore, it is necessary to choose the plant species composing community forests with high absorption of CO_2. The CO_2 absorption level is an indicator of increased productivity and growth speed of trees.

2. Methods

This study was conducted in Purbalingga at two locations differentiated by the 700 m altitude contour line, the lowlands less than 700 m, and the highlands above 700 m. The Notog village of Patikraja sub-district and Kutaliman village of the Kedung Banteng sub-district represents the lowlands. In contrast, the Sangkan Ayu village of Mrebet sub-district and Serang village of Karangreja sub-district characterize the highlands.

This study used a survey method with a stratified random sampling technique. The strata used in were altitude, and the study site was grouped into two lowlands and highlands. In each location, three community forests were selected as replicates. Then in each community forest, the vegetation structure and composition were recorded, and the leaves were sampled from each species of both trees and seasonal plants for carbohydrate content analysis.

The vegetation found in the community forests was sorted based on its type, trees, or undergrowths (annual plants). The sample collection was conducted using square quadrats. The size of the quadrat for trees was 10 x 10 m, while 2 x 2 m were used for annual crops and placed within the quadrat of the tress The leaf samples were also taken from the plants within sampling quadrats. The leaf samples collection time was from 3:30 to 4:30 local time before photosynthesis occurred, and resampled from 10:00 to 11.00 when the photosynthesis was optimum. The leaf samples were then soaked in 70% alcohol to prevent further photosynthesis and respiration. The dried leaf samples were then analyzed for the carbohydrate content in the laboratory.

Measurement of carbon dioxide absorption was carried out at the FMIPA UNSOED Organic Chemistry Laboratory. CO_2 absorption was determined by measuring the carbohydrate content of leaves. Measurements of carbohydrate mass and carbon absorption were carried out following [5] as follows.

Samogyi Nelson [5] formula to estimate carbohydrate content. Massa $C_6H_{12}O_6$ = % fresh carbohydrates X leaf fresh weight

Where leaf fresh weight = 30 gr, % fresh carbohydrates = [(100% - leaf water content)/100] X dry carbohydrates. Leaf water content = [(leaf fresh weight – leaf dry weight)/(leaf fresh weight)] X 100%. Dry carbohydrate = [(carbohydrate absorb in the sample/mean of carbohydrate standard) X (100/0.2) X (20/1) X (100%)]/1,000,000.

Carbon dioxide mass calculation was based on the following equation. Massa CO_2 = massa $C_6H_{12}O_6$ x 1,467

The CO_2 absorption per leaf sample area (D) was based on, D = mass of CO_2/leaf area. The leaf area was calculated from the 30 g of leaf weight.

The CO_2 net absorption per leaf area unit per hour (Dt) was estimated according to Dt = CO_2 absorption in leaf sample area/difference in sampling time.

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The CO_2 net absorption per leaf blade per hour (Dl) was as follows, Dl = Dt X leaf blade area.

The CO_2 absorption of a tree (Dn) was calculated by Dn = Dl x the number of leaves in a tree.

The CO_2 absorption per tree per year (Dy) was Dy = [{Dn x t} + {Dn (A - t) x 0,46}] x 365

Where Dn: absorption per tree per hour, A: mean of maximum period of light in a day (hour/day), t: mean of actual light in a day (hour/day), 0,46: a ratio of the mean of photosynthesis rate in a cloudy to a sunny day [6], 365: days in a year (the annual plant was based on its life period).

Vegetation composition and structure data were analyzed using the Importance Value Index. The plant species CO_2 absorption capacity was determined using analysis of variance (ANOVA) followed by Duncan's test.

3. Results

3.1 Community Forest Vegetation Structure

Plant species in community forests of both lowland and highland were 27 species consisting of 21 trees and 6 annual plants. The trees found were teak (*Tectona grandis*), Sengon (*Paraserianthes palcataria* (L.) Nielson, Jabon (*Neolamarckia cadamba* (Roxb.)), Mahogany (*Swietenia mahagony*), white teak (*Gmelina arborea* Roxb.), Acacia (*Acasia mangium*), Angsana (*Pterocarpus indicus* Willd.), Rubber (*Havea braziliensis*), Johar (*Senna siamea* (Lamk.)), Tisuk (*Hibiscus macrophyllus*Roxb.), Coffee (*Coffea robusta*), Cloves (*Senna siamea* (Lamk.)), Coconut (*Cocos (Cocos)) nucifera*), Melinjo (*Gnetum gnemon*), Durian (*Durio zibetinus*), Mango (*Mangifera indica*), and Rambutan (*Nephelium lappaceum* L.), while the annual plants Corn (*Zea mays*), Cassava (*Manihot utilisima*), Taro (*Calocasia esculenta*), Long Beans (*Vigna unguiculata*), Canna (*Canna edulis*), and Sweet Potato (*Ipomoea batatas*).

3.2 Plant Carbon Dioxide Absorption

The CO_2 absorption capacity of vegetation composing community forest is presented as per leaf blade and tree. The lowland and highland trees showed a significant difference in the CO_2 absorption capacity at $p < 0.05$. Meanwhile, the annual vegetation was not significantly different. The average CO_2 absorption capacity of trees in the lowlands was 46,2549 kg. trees-1.year-1 whereas in the highlands was 44,1705 kg. tree-1.year-1. Based on these data, it can be resolved that the CO_2 absorption capacity of trees grown in lowland community forests tends to be higher than in highlands. The CO_2 absorption capacity among species of both lowlands and highlands showed a very significant difference ($p < 0.01$). The tree species having the highest CO_2 adsorption capacity was teak followed by jabon, rubber, coffee, white teal, coconut, mango, and tisuk (Table 1), while the annual vegetations were canna, long beans, corn, and taro (Table 2). The tree and annual vegetation CO_2 absorption capacity levels were consistent in both lowlands and highlands.

Tabel 1. The CO_2 absorption capacity of the private forest trees

No.	Plant Species	The CO_2 absorption capacity of the trees			
		Lowland		Highland	
		(g/leaf blade/hour)	(kg/tree/year)	(g/leaf blade/hour)	(kg/tree/year)
1	Acasia	0.0552^{ghij}	48.7532^{ghi}	0.0507^{ghij}	44.7277^{ghi}
2	Cengkeh	0.0462^{ghij}	30.6868^{ijk}	0.0424^{ghi}	28.0670^{ijk}
3	Dukuh	0.0772^{fg}	53.5725^{ghi}	0.0671^{fg}	46.4899^{ghi}
4	Durian	0.0278^{ijkl}	16.9385^{jk}	0.024^{ijk1}	14.5883^{jk}
5	Jabon	0.7298^{b}	507.8859^{b}	0.7459^{b}	518.9810^{b}
6	Jati	1.0943^{a}	462.2195^{c}	0.9354^{a}	395.5993^{c}
7	Jati Putih	0.1835^{d}	91.4268^{f}	0.1753^{d}	87.3424^{f}
8	Johar	0.0016^{l}	$50.4939g^{h}$	0.0018^{1}	55.2624^{gh}
9	Karet	0.2664^{c}	355.0136^{d}	0.3243^{c}	431.4002^{d}
10	Kelapa	0.1771^{d}	306.0298^{e}	0.1558^{d}	269.2848^{e}
11	Kopi	0.2941^{c}	597.7152^{a}	0.2576^{c}	525.8415^{a}

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No.	Plant Species	The CO_2 absorption capacity of the trees			
		Lowland		Highland	
		(g/leaf blade/hour)	(kg/tree/year)	(g/leaf blade/hour)	(kg/tree/year)
12	Mahoni	0.0974^{ef}	47.5888^{ghi}	0.0951^{ef}	46.4844^{ghi}
13	Mangga	0.1192^{e}	17.0974^{jk}	0.1153^{e}	16.5419^{jk}
14	Melinjo	0.0580^{ghi}	23.4649^{jk}	0.0538^{ghi}	21.8131^{jk}
15	Nangka	0.0732^{fgh}	48.7716^{ghi}	0.0667^{fgh}	44.5145^{ghi}
16	Rambutan	0.0254^{ijkl}	95.8953^{f}	0.025^{ijkl}	94.1247^{f}
17	Sawo	0.0459^{ghijk}	68.4200^{g}	0.0386^{ghijk}	58.9512^{g}
18	Sengon	0.0067^{kl}	21.4577^{jk}	0.0072^{kl}	22.6329^{jk}
19	Sirsak	0.0343^{hijkl}	10.0042^{jk}	0.036^{hijkl}	10.5151^{jk}
20	Sukun	0.0182^{jkl}	17.8324^{jk}	0.0155^{jkl}	15.2302^{jk}
21	Tisuk	0.1260^{e}	42.7938^{ghi}	0.101^{e}	34.3499^{ghi}

Numbers followed by the same letters in one column indicate no significant difference in the 5% DMRT.

Tabel 2. The CO_2 absorption capacity of the annual plants

No.	Plant Species	The CO_2 absorption capacity of the trees			
		Lowland		Dataran Tinggi	
		(g/leaf blade/hour)	(kg/pohon/tahun)	(g/leaf blade/hour)	(kg/pohon/tahun)
1	Jagung	0.4126^{c}	1.6081^{c}	0.4180^{c}	1.5729^{c}
2	Ganyong	0.9648^{b}	4.1829^{a}	1.1170^{b}	5.7804^{a}
3	K.Panjang	0.0846^{d}	4.3431^{ab}	0.0957^{d}	4.9158^{ab}
4	Singkong	0.1618^{d}	3.7256^{bc}	0.1588^{d}	2.2852^{bc}
5	Talas	1.6640^{a}	2.4294^{c}	1.3235^{a}	1.9324^{c}
6	Ubi Jalar	0.0961^{d}	2.8820^{bc}	0.1267^{d}	3.1860^{bc}

Numbers followed by the same letters in one column indicate no significant difference in the 5% DMRT.

4. Discussion

The composition of community forest vegetation, when compared between lowland and highland, does not show any substantial difference. The reason is that the management objectives of their owners influence the management of community forests. The objectives of community forest management are to meet the financial benefit of the owners. The economic benefits of community forests with the tree species planted were used as savings to fulfill annual needs. When owners need some funds, the trees will be logged and sold. Whereas annual vegetation in community forests are beneficial as food stock to meet daily, monthly, and seasonal needs. When the food supply decrease, farmers will take food crops such as cassava and sweet potato from the community forest.

The five dominant tree species in community forests are wood-producing trees such as teak, sengon, mahogany, acacia, and white teak. The farmers intentionally grow all those five species to produce wood as a family saving. When farmers need a relatively significant amount of money, they will cut down the tree for sale. In addition to woody trees, non-wood producing tree species such as coffee, clove, mango, rambutan, durian, and rubber were also cultivated. The goal of farmers managing these non-timber producing trees is to use as a source of income. The tree species used as annual income include coffee, cloves, mangoes, rambutans, and durians, whereas the sources of daily income are coconut, coffee, and rubber.

Rubber tree-based community forests are widely grown in lowland areas as in the Village of Kutaliman, Kedung Banteng sub-district. The goal of farmers to develop rubber commodities is to get a higher economic value, production not only from wood but also from rubber latex that can be harvested every day. In contrast to wood-producing commodities such as teak, sengon, and jabon, farmers only get the benefits of wood with a relatively long investment period of more than 5 years.

The different absorption capacity of community forest trees in the lowlands and the highlands most likely due to the limited situation to rivers. In general, tree species developed in community forests are species that are adaptive to lowland areas. Teak, jabon, rubber, and mahogany grow optimally in the lowlands to an altitude of <700 ml while the difference in CO_2 absorption of seasonal plants between lowlands and highlands possibly due to the distribution of seasonal plant species that found to be very broad [7] The distribution area of annual crops such as canna, long beans, corn, and taro is up to 1,500 m above sea level [8]. The natural distribution area of annual crops has no barrier so they can grow in both lowlands and highlands.

The high CO_2 absorption capacity of teak, jabon, rubber, coffee, white teak, coconut, mango, and tisuk trees and canna, taro, corn, and long beans in the seasonal crop seems to be related to leaf surface area per strand. The leaf surface area of plant species that have high absorption is more significant than other plants that have low CO_2 absorption. Based on this, it suggests that the higher the leaf area per leaf, the greater the CO_2 absorption per leaf, and vice versa. The large leaf surface area per strand increases the ability to absorb more CO_2 so that the process of photosynthesis in leaves with a larger leaf surface area will be higher than leaves that have smaller leaf surface area.

The leaf surface area is related to the number of stomata, the more leaf surface area, the more stomata. The relationship between the number of stomata to CO_2 absorption is directly proportional. Thus it can be said that the higher the leaf area, the more the number of stomata, the CO_2 absorption will also increase. The same condition was also found by several studies reporting the area per leaf influences the absorption capacity of each leaf [9, 10].

5. Conclusion

1. The absorption of CO_2 by community forest vegetation differs between lowland and highland, and the growth of trees was concluded to be significantly influenced by the altitude.
2. The absorption capacity of trees in lowland community forests was higher compared to the highlands.
3. Tree species found having high CO_2 absorption were teak, jabon, rubber, coffee, white teak, coconut, mango, and tisuk, while annual crops were canna, long beans, corn, and taro.

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