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Estimation of Carbon Stock and Absorption of Carbon Emissionin Theagroforestry System of Peatland

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Abstract: One effort to maintain C stockvegetativelyin nature is thr[1]ough agroforestry program on peatland. Through agroforestry system the concentration of CO_2 in the atmosphere can be reduced, and the result is carbohydrate accumulated in plant biomass. The level of CO_2uptake in the atmosphere varies depending on the typesof constituent plantsand the age ofland.The objectives of this study wereto analyze 1) the carbon content stored in agroforestry system on peatland, 2) the ability of agroforestry system on peatland to absorb carbon emission (CO_2), 3)the economic value through agroforestry on peatland. The benefits of this study were to provide important information in the effort torehabilitate the degraded peatland,which was developed through agroforestry system. Moreover, the results of this study could be used as the reference data to implement the program ofReducing Emission from Deforestation and Degradation (REDD).

The results showed that 1) the number of carbon content for jelutung plants in agroforestry pattern was 1.4430 tons/ha,and for intercrops4.185 tons/ha which consisted of corn, mustard, chili and leek,2) the ability of staple crops and intercrops to absorb CO_2in agroforestry patternwas20.496 tons/ha, and 3) the benefit valuewhich wasobtained by agroforestrypattern on peatland wasIDR 375,322,625 in a year, where the intercrops could be cultivatedseveral times a year. It is suggested to conductfurther study to calculate the carbon content of staple crops andintercrops and the ability ofother staple crops and intercrops to absorb CO_2.
Keywords : peatland, agroforestry, carbon emission.

Introduction

Peatland is a large place for the storage of carbonelement. Carbon is known as the essential substance of greenhouse,which plays a role in global warming. In fact, the conversion of peat forest has failed and led to the creation of degraded lands. The environmental damage,ecosystem function damage, biodiversity loss and other impacts become inevitable. However,another impact that does not get much concern, peatland degradation,can also be threatening that causes an increase in emissions of carbon dioxide (CO_2) in atmosphere.

The existence of peatlandis increasingly perceived important especiallyin storing more than 30 percent of terrestrial carbon, playing an important role in hydrological cycle and maintaining biodiversity. In some places,the good managementof peatland hascreated a positive impact on the environment and the economic growth, while the poor management has created a negative impact on the environment, economy,and human life.

The effort to maintain the Cstockvegetativelyin nature isthrough agroforestry program on peatland. Through agroforestry system the concentration of CO_2 in the atmosphere can be reduced, and the result is carbohydrateaccumulated in plant biomass. The level of the uptake of CO_2in the atmosphere varies, depending on the typesof constituent plantsand the age of land.Peatland is particularly susceptible to fire,unproductive thus less utilized. As the result, many peatlands are abandoned.

In order to decrease and compensate for deforestation activities in the areas of CO_2production and conservation, it is highly advisablethat the rehabilitation efforts are in line with the directives and the purposes of the development of planted forests, one of which is with agroforestry pattern. The study results showed that about 15-36 billion tons of carbon could be stored in plantedforest with the assumption that human activities resulted in carbon emissions of 5-6 billion tons per year, indicating that the planting in tropics couldstore the equivalent of 2.5 to 7 years of emissionvalue contained in a spread areaofplanted forest[1].

Soil with high pyrite content is potential acid sulfate soil.The period of acid sulfate soil formation also occurs simultaneouly withthe period of peat soilformation. Acid sulfate soil is formed as a result of the drainage of themain material rich of pyrite.Agroforestry pattern can reducecarbon emission, improve environment, and increasefarmers' income while still maintaining the environmental sustainability. The objectives of this study were:

1. To analyze the carbon content stored in agroforestry systemon peatland.
2. To analyze the ability of agroforestry system on peatland to absorb carbon emission(CO_2).
3. To analyze the economic value through agroforestry program on peatland.

The benefit of this study was to provide information important forthe efforts to rehabilitate the degraded peatlands, which was developed through agroforestry system.In addition to it, the results of this study could be used as reference data in the implementation of the program of Reducing Emission from Deforestation and Degradation (REDD).

Methods

Place and time of study

The study was conducted in Kalampangan Village,Sabangau Sub-district, Palangkaraya, Central Kalimantan.It wascarried out for 8(eight) months, from May to December 2012, including the study preparation,data collection,data processing and studyreport.

Objects and Equipment

The objects used in this study were trees, ground vegetation, litter and soil in agroforestry.

Table 1. Equipment Used inStudy

No	Equipment	Usage
1	Meter	Measuring the area
2	Phiban	Measuring tree diameter
3	GPS	Determiningthe coordinate of observation spot
4	Sample Ring	Collecting soil sample
5	Oven	Drying litter sample
6	Scale	Weighinglitter sample
7	Knife	Clearing/cutting branches
8	Sack	Place to put litter samplecollected
9	Plastic label	Labelling/marking on tree
10	Tally sheet	Recording observation data in field
11	Camera	Documenting the study process
12	Calculator andComputer	Processing data
13	Stationery	Writing Data

Study Procedures

Primary Data Collection

The procedures:

1. The determination of the location of the study was carried out purposively, the location where the land was managedwith agroforestry systemon peatland.
2. The determination of Measurement Sample Plot(MSP) was conducted using purposive sampling method with a plot size of 20 x 50 m (area = 0.1 ha).There were 3 plots made, from each of which was randomly taken 3 spotswith a size of 0.5mx 0.5 mfor observation/sampling ofground vegetationand litter.
3. The tree measurementwas conducted by measuring the tree height and diameter on the plot size of 20 mx 50 m.
4. The soil sampling was carried out in 3 spots within the plot size of 20 mx 50 m, by taking the soil bulkusingsamplering.

Secondary Data Collection

The datausused in the study weresecondary and primary data related to thestudy activities.Secondary data were the data from various authorized institutions in regency,districtand village, as well as other study results related to these study problems while primary data were obtained from direct observation in the field.

The secondarydata required in this study were:

1. The general overview data ofthe study location, which includes the position and width, topography, soil and geology, as well as other supporting data sources.
2. The climate data including rainfall, total rainy days (days), maximum monthly rainfall (mm) and heaviness of rainy day (mm)obtained from therain station and the local Meteorological and Geophysical Agency (MGA).

Analysis Method

Estimation ofCarbon Content of Tree

The method to estimate the carbon content of agroforestry land wasusing allometric equation developed by Brown[2]and Kettering[3]:

$$W = BJ \times 0,19\ D^{2.37}$$

Note :

BJ = wood specific gravity(g/cm^3)
W = dry biomass of tree(kg)
D = tree diameter at chest height (cm)

Furthermore, to estimate the content or the stock of carbon(C in kg) wasby multiplying biomass with conversion factor[4].

$$C = 0.5\ W$$

Note:

W = tree biomass (kg)

Estimation ofCarbon of Ground Vegetation

The estimation of ground vegetation biomass was conducted by cutting down all the ground vegetations(shrubs, grasses, herbs), which grew in the observation spot. The estimation of ground vegetation carbon was calculated using this equation:

$$WKT = \frac{WKC}{WBC} x WBT$$

Note:
WKT = total dry biomass (kg)
WBT = total wet biomass (kg)
WBC = wet biomass sample (kg)
WKC = dry biomass sample (kg)

Ability of Agroforestry Plants to Absorb CO_2

The ability of agroforestry stands to absorb $CO_2$is calcullated through the following approach[4].
W_{co_2} = Wtc x 3.67
Note:

W_{C02} = the amount of CO_2 absorbed
Wtc = total carbon content of the stand(tons/ha)
3.67 = equivalent/conversion rate of carbon element (C)into CO_2
(Atomic mass = 12 O=16, CO_2=>(1x12) + (2x16) = 44; Conversion=>(44:12) =3.67)

Economic Value

Calculating Value of Wood

According to Harun[5],to calculate the value of woodin agroforestry pattern ofjelutung can be formulated as follows:

Wood Value = volume/ha x wood price

Value of JelutungSap

According to Harun[5], to calculate the total income derived from theJelutung Sapcan be formulated as follows:

Value of sap = sap production/tree/year x price

The price of Jelutung Sap was based on the price of naturalJelutung Sapused during the study.

Valueof intercrop(vegetable)

Farmingincomeor intercrop value isa multiplicationbetween production and selling price which is defined by the following formula:

Tri = Yi x Pi

Tri = Totalincome
Yi = Production ofcrop i
Pi = Price of intercrop i

Intercrop price is the price obtained at the location at the time of price transaction between buyers and farmers.

Results and Discussion

Carbon Content of Agroforestry Staple Crop

Based on the measurement of jelutung trees in agroforestrypattern, it obtained biomassby 837.393545 /kg / ha (Table 2).

Table 2.Biomass Content of Jelutung Trees in AgroforestryPatternin KalampanganVillage, Palangkaraya

No	Type	Height	Diameter	Volume	Specific Gravity	Biomass
1	Jelutung	6.4	8.96	0.0242	0.56	19.227004
2	Jelutung	6.7	8.8	0.0244	0.56	18.423221
3	Jelutung	6	9.92	0.0278	0.56	24.472272
4	Jelutung	6	9.28	0.0243	0.56	20.894421
5	Jelutung	7.1	9.92	0.0329	0.56	24.472272
6	Jelutung	5.9	8.32	0.0192	0.56	16.129983
7	Jelutung	8	9.76	0.0359	0.56	23.547115
8	Jelutung	7.6	9.6	0.0330	0.56	22.642504
9	Jelutung	6.7	9.44	0.0281	0.56	21.758315
10	Jelutung	7	9.12	0.0274	0.56	20.050693
11	Jelutung	6.1	9.92	0.0283	0.56	24.472272
12	Jelutung	6	10.87	0.0334	0.56	30.395245
13	Jelutung	6.7	8.01	0.0202	0.56	14.741806
14	Jelutung	6	8.64	0.0211	0.56	17.639213
15	Jelutung	6.2	7.21	0.0152	0.56	11.488100
16	Jelutung	5.6	6.73	0.0119	0.56	9.757472
17	Jelutung	8	9.76	0.0359	0.56	23.547115
18	Jelutung	7.7	9.28	0.0312	0.56	20.894421
19	Jelutung	6.6	11.83	0.0435	0.56	37.146292
20	Jelutung	8.4	11.51	0.0524	0.56	34.808888
21	Jelutung	7	9.6	0.0304	0.56	22.642504
22	Jelutung	8.7	10.71	0.0470	0.56	29.345578
23	Jelutung	7.1	9.12	0.0278	0.56	20.050693
24	Jelutung	6.3	8.17	0.0198	0.56	15.449268
25	Jelutung	9.7	13.1	0.0784	0.56	47.301466
26	Jelutung	8.4	9.76	0.0377	0.56	23.547115
27	Jelutung	9	9.92	0.0417	0.56	24.472272
28	Jelutung	6.8	11.38	0.0415	0.56	33.884321
29	Jelutung	8.2	12.78	0.0631	0.56	44.608719
29	Jelutung	8.7	10.55	0.0456	0.56	28.317177
30	Jelutung	9.6	11.99	0.0650	0.56	38.348033
31	Jelutung	9.7	10.08	0.0464	0.56	25.418100
32	Jelutung	9.9	11.99	0.0670	0.56	38.348033
33	Jelutung	9	10.39	0.0458	0.56	27.309923
34	Jelutung	10.4	12.78	0.0800	0.56	44.608719
35	Jelutung	9.7	12.62	0.0728	0.56	43.296451
36	Jelutung	6.8	8.64	0.0239	0.56	17.639213
37	Jelutung	6.6	8.48	0.0224	0.56	16.874845
38	Jelutung	6.4	6.89	0.0143	0.56	10.316234
39	Jelutung	6	7.05	0.0140	0.56	10.893058
40	Jelutung	6	7.21	0.0147	0.56	11.488100
41	Jelutung	6.5	8.17	0.0204	0.56	15.449268
42	Jelutung	11	11.99	0.0745	0.56	38.348033
43	Jelutung	11.5	11.83	0.0758	0.56	37.146292
44	Jelutung	10.6	12.46	0.0775	0.56	42.006780
45	Jelutung	10.7	10.08	0.0512	0.56	25.418100
46	Jelutung	10.5	10.24	0.0519	0.56	26.384722
47	Jelutung	10.3	9.6	0.0447	0.56	22.642504
48	Jelutung	9.5	11.67	0.0609	0.56	35.966614
49	Jelutung	11.3	12.78	0.0869	0.56	44.608719
50	Jelutung	13	13.1	0.1051	0.56	47.301466
	Total			1.4430		837.393545

Source: primary data in 2013

Biomass content ofjelutung treein agroforestrypattern was8.37 tons/ha, while the average carbon stock per hectare for staple crops was 4.185 tons/ha.The carbon stockon peatlandfor staple crops was big enough. This value was smaller than thevalue in uncultivated peatland for agriculture or through agroforestry pattern.

Table 3. Biomass Observation Sheet of Agroforestry Ground Vegetationin Kalampangan Village of Sabangau Sub-district of Central Kalimantan

Plant Species	Sample Code	WBt (A) (g)	WBc (B) (g)	WKc (C) (g)	WKt (D) = C/BxA (g)	WKt (kg)
Ground Vegetation	1	232.9	200	42.5	49.491	0.049
	2	979.3	900	167.7	182.476	0.182
	3	428.7	400	22.9	24.543	0.025
	4	325.4	300	17.2	18.656	0.019
	5	783.1	700	77.5	86.700	0.087
	6	543.0	500	55.9	60.704	0.061
Average					70.428	0.070

Sources: Primary data in 2013

Pigure 1. The Intercrop of cor

Table 4.Average Carbon Stockof Treein Agroforestry

Location	Total Biomass/ha (kg/tree) (A)	Biomass (kg/M2) (B)	Biomass (Ton/ha) (C)	C Stock 0.5 x C (D)	Benefit Value D x 9,875 (IDR)
Agroforestry	837.39	0.837	8.37	4.185	40,803,750

Source: Primary data in 2013 Description: Assumption that 1 kg of carbon = U.S. $ 1 or equivalent to IDR 9,875

Table 5.Carbon Stock of Ground Vegetation in Agroforestry

Location	WKt (A)	Biomass (kg/M2) (B)	Biomass (Ton/ha) (C)	C Stock 0.5 x A (D)	Benefit Value D x 9,875 (IDR)
Agroforestry	0.070	0.28	2.80	1.4	13,650,000

Source: Primary data in 2013 Description: Assumption that 1 kg of carbon = U.S. $ 1 or equivalent to IDR 9,875

Pigure 2. The Intercrop of chili

Ability of Agroforestry Systemon Peatland to Absorb CO_2 Emission

Forests are the lungs of the earth that allow us to still haveclean air and sufficient oxygen. Forests also absorb carbon emission so that the earth is still protected from temperature rise and extreme climate change. However, the function of forests to absorb carbon has a limit. It is revealed from the results of a recent study released by the European Forest Institute.

The function of carbon sequestration by forests is declining due tothe increasing deforestation. Hence, the landswhich have been deforested should be conserved. One of ways to do so is by agroforestry system. Through agroforestry, it is expected that the degraded lands can be reforested.

Based on the analysis results, the ability of staple crops in agroforestry (jelutung trees)wereable to absorb carbon emission by 15,385 tons/ha. Meanwhile, ground vegetations(intercrops) consisting of corn, mustard, leek and chiliwereable to absorbcarbon emission by5,138 tons/ha.

The further researcheson the ability of trees to absorb carbon (C) has been conducted by the International Centre for Research in Agroforestry (ICRAF), Southeast Asian Regional Center for Tropical Biology (BIOTROP), Bogor Agricultural Institute(IPB),InstituteforResearch and Development of Forestry of Forestry Department, and the Ministry of Environment. The researcheswere specialized on the techniques of measurement and calculation ofCcontained in various types of forest plants.Research and Development Center of Forest and Natural Conservation has examined the ability to absorb carbon and the results showed that C content varied according to the study site,the forest tree species and the stand age. The C content of acacia trees in South Sumatra was 16.64 tons/ha/year,greater than the C content of Acacia stands aged 10 yearsold in West Java, which was only 9.06 tons/ha/year.Itwashigher than the C content of jelutungon peatland becausethe canopy ofjelutung wasthinner than the canopy of acacia or sengon.

Economic Value in AgroforestryPattern

The outcome of all types of plants and ground vegetationswas measured based on the full value as reflected in the market value. The method used in the assessment of direct benefit was the direct approachon market value. This approach calculated the type and total products that can benefit people living on peatland of the study area and it wasmultiplied by the prevailing market price of each unit of product produced.

Judging from the market economicvalue, the jelutung tree and jelutung sap produced from peatland area was a type of plantshavinga high economic value.The complete estimation of the economic value of each type ofplants and ground vegetationswhich provided direct benefit is presented in Table 6.

Table 6. Market EconomicValue of Staple and SeasonalCrops on Peatlandof Ex Transmigration Area in Kalampangan Village

No	Direct Benefit	Economic Value(1 ha)	Operational Cost	Net Benefit
1	Jelutung Tree	12,987,000*	6,300,000	6,687,000*
2	Jelutung Tree Sap	34,020,000	4,200,000	29,820,000
3	Corn	100,996,875	17,550,000	83,446,875
4	Mustard	162,093,750	24,750,000	137,343,750
5	Chili	63,000,000	27,750,000	35,250,000
6	Leek	111,475,000	28,700,000	82,775,000
	Total of Direct Benefit	484,572,625	109,250,000	375,322,625

Source: Primary Data, 2013 Note: * Benefit Value of jelutung at age of 8 years

The results of the approach shown in Table 6indicated that the economic value of staple and seasonalcrops directly obtainedwas approximately IDR375,322,625 million/ha with the operational costs ofIDR 109,250,000.

Conclusion and Suggestions

Conclusion

1. The value of carbon content of jelutung on peatland with agroforestry pattern was4,185 tons/ha/year.It was smaller than the carbon content of acacia trees in South Sumatra and senggon in West Java.
2. The ability of staple crop (jelutung) to absorb carbon emission was15,385 tons/ha/year, while the ability of intercrops to absorb carbon emission was 5,138 tons/ha/year.
3. The benefitvalue that was able tobe obtained through agroforestry program washigh enough and promising for farmers. The total benefit value of jelutung and intercrops wasIDR 375,322,625/ha/year.

Suggestions

This study is only a model of agroforestryon peatlandthat can be used as a reference for further study so that the utilization of peatland and the ability of forest plantsto absorb carbon emission can be optimalized.

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