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Contribution of Ameliorant Application on Carbon Balance in Rice (Oriza sativa L.) Cropping in Peatland

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ABSTRACT

Expansion of agricultural land in Indonesia is needed to accomplish the future national food demand. Expansion of agricultural land has been focused on marginal land such as peatland. The studies was carried out by using 12 microplots with each have a dimension of 1,5 m x 1,5 m x 1 m in IAERI and was filled with peat from South Kalimantan. Amelioration treatments such as dolomite, volcanic ash, Pugam peat fertilizer, Fe fertilizer, nitrification inhibitor and control were established as treatments to the microplots. After amelioration applications, the plots was planted by Inpara 2 rice cultivar. Data of the result was analyzed by Analysis of Variance (ANOVA) and Duncant Multiple Range Test (DMRT). The result showed that the net carbon was highest control treatment (3785 kg-C/ha) followed dolomite, Fe fertilizer, NI (nitrification inhibitor), Pugam peatland fertilizer i.e 3238, 2082, 1574, and 1439 kg-C/ha, respectively. The lowest net carbon was from volcanic ash (-712 kg-C/ha).

Keywords: C-sequestration, IAERI, net-carbon, peat soil, soil ameliorant

INTRODUCTION

Peatland ecosystem is one that has a large potential to be developed as agricultural land because it has a wide area. Use of peatlands for cultivation of agricultural crops must be done carefully and considering the depth, moisture, and brittleness properties of peat. However, the constraints encountered in the use of peat as agricultural land, among others, are low nutrient availability, high acidity and content of organic acids that limit productivity high peat (Barchia, 2006).

Amelioration of peatland is one of the efforts to boost peat productivity through improvement of physical and chemical conditions of peat. Criteria of good emeliorant for peatland are (1) having a high base saturation (BS), (2) able to significantly increase the pH level, (3) able to improve soil structure, (4) contains a complete nutrient, and (5)able to degrade toxic compounds, especially organic acids. Ameliorant material can be either organic or inorganic material (Susilawati *et al*., 2011).

Climate change is a global phenomenon which is marked by changes in temperature and rainfall distribution. The biggest contributors to the occurrence of these changes are gases in the atmosphere which are often called as greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4) and nitorus oxide (N_2O) whose concentration is constantly increasing. These gases have the ability to absorb long-wave radiation that is heat so that the temperature of the earth will increase if the amount of these gases in the atmosphere increases (Najiyati *et al*, 2005).

Giving ameliorant into peat especially rich oxidant is capable of suppressing the emission of greenhouse gases. Previous research done by Indonesian Agricultural Environment Research Insitute (IAERI) has showed that the highest percentage reduction in GWP in peat soils occurred with manure (21.8%), while the provision of dolomite and manure in

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peatland can reduce their GHG emissions by 20 and 19% (Anonim, 2009).

CO_2 is absorbed by plants through photosynthesis as a raw material, forming carbohydrates which further are translocated to all parts of the plant and eventually deposited in the leaves, stems, flowers and fruit. The process of accumulation of food reserves in the form of carbon (C) in the body of plant life is called as carbon sequestration process (C-sequestration). The amount of C stored varies between different fields, depending on the diversity and density of existing vegetation and soil types as well as the way it is managed. In the peat ecosystem, C 3 components are stored in biomass, necromass, and soil organic matter (Hairiah dan Rahayu, 2007).

Biomass is the mass of vegetation that is still alive, namely the plant canopy, lower plants (weeds). Measurement of the amount of C stored in the body plant life (biomass) on a piece of land can describe the amount of atmospheric CO_2 absorbed by plants.

Necropsy is the mass of the parts of trees that have died either still upright on land (trunk or stump plants), or which has been lying on the ground level that has not been weathered. Measurement C still stored in the parts of plants that have died (nekromasa) indirectly describes CO_2 not released into the air through combustion.

Soil organic matter is the form of the rest of living things (plants, animals and humans) who have experienced weathering partly or in whole and has become part of the soil.

Carbon in the soil will give dark color of the soil and biological and chemical, carbon in the soil can increase soil productivity. Organic carbon is a major component of soil organic matter because the composition reaches 48% - 50% of the total organic matter weight (Nelson, and Sommers, 1982).

This study aimed to obtain information on the carbon balance of rice planting in peat given ameliorant materials. Carbon balance research in the agricultural sector is essential to determine net GHG emissions in the peat soil.

MATERIALS AND METHODS

The experiment was conducted at the experimental farm of Indonsian Agriculture Environmental Research Institute in Dry Season 2011. Peat taken from Banjarbaru district (South Kalimantan) was dumpt in microplots measuring 1.5 m length x 1.5 m width and 0.8 m depth. The experiment was arranged using a randomized block design with two replications and six treatments. The treatments were without ameliorant (refer as Kontrol treatment hereafter), dolomite 2 tons/ha (refered as Dolomit treatment), peat fertilizer 750 kg/ha (refered as Pugam), ash volkan 10 tonnes/ha (refered as Abu Vulkan), Fe fertilizer (Fe_2SO_4) 1 ton / ha (refered as Pupuk Fe) and materials inhibiting nitrification at the rate of 22.5 kg/ha (refered as NI treatment). Ameliorant material incorporated into the peat before planting.

Plant height and number of tiller were measured every 2 weeks starting at 14 days after planting (DAP). Dry grain weight, dry milled grain (moisture content 14%) weight, and plant biomass (dry) were observed at harvest. Biomass plants were taken from the base of the stem which is adjacent to the land. Soil pH and redox potential (*Eh*) were monitored by ORP meter in weekly basis through out plant growth period.

Carbon content of plants was measured at harvest by using the method of combustion with total CN analyzer tool.

Carbon balance was calculated based on the formula:

$$\text{Net Carbon (kg-C/ha)} = {}^{1}\text{C-organic Content (kg-C/ha)} - \text{GWP (kg } CO_2\text{-C/ha)}$$

$$^{1}\text{C-organic Content} = (^{2}\text{C-Orgg x } ^{3}\text{GY} + (^{4}\text{C-Org r x } ^{5}\text{wr}) + (^{6}\text{C-Orgj x } ^{7}\text{ws}) + (^{8}\text{C-Orgs x } ^{9}\text{ww}) \ldots\ldots (1)$$

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Where:
[1]C-Org Cont= C-organic Content (kg-C/ha); [2]C-Orgg = C-organik grain (%); [3]GY = grain yield WC 14%; [4]C-Org r = C-organic root (%); [5]wr = weight of root WC 30%; [6]C-Orgs = C-organic straw (%); [7]ws = weight of sraw WC 30%; [8]C-Orgw = C-organic weed (%) and [9]ww= weight of weed WC 30%.

C-organic carbon content in the biomass above and below the plant biomass, both rice plants and weeds were also calculated. The data was used to determine the amount of C-organic absorption of the total gas emissions. The end result of this activity is the net value of the carbon of each treatment. Net C is the differences between total emissions of carbon equivalent-C released and C absorption from plant biomass (biomass above and below the biomass).

Carbon content data, the plant parameters and yield components were analyzed using ANOVA (analysis of variance). The difference from each median values was determined using Duncan test at P = 0.05. Statistical analysis was performed by using the software SAS (statistical analysis system) version 9.1.3

RESULTS AND DISCUSSION

Redox Potential changes

Potential redox during rice growing in peat ranged from +4 and -299 mV (Figure 1). Under conditions of stagnant organic materials decay more slowly and less perfectly than in dry conditions. Provision of Fe fertilizer resulted the lowest *Eh* compared to other treatments. The highest Eh values indicated in the treatment of volcanic ash. This suggests that the high content of oxidants in the material prevailed the reduced conditions of peat.

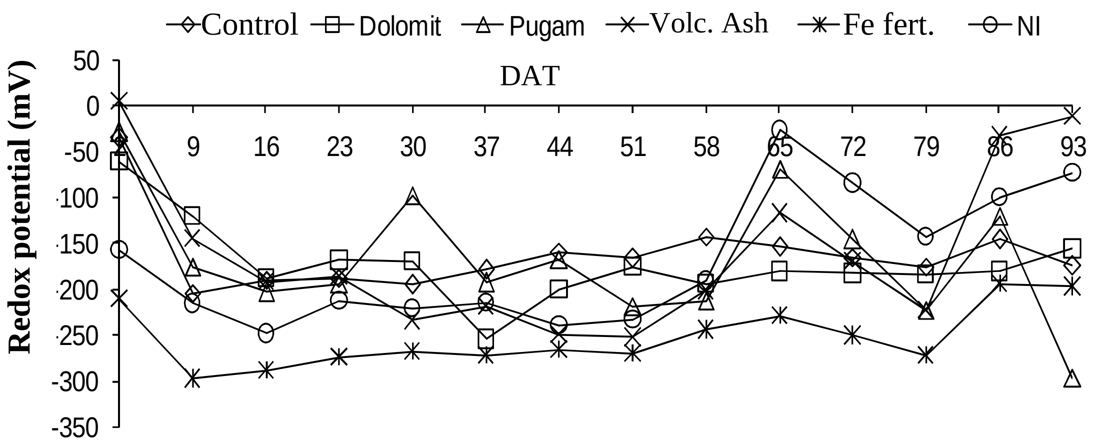

Figure 1. Changes in redox potential (Eh) of several treatments ameliorant in peat planted with rice in DS 2011

The pH value in each treatment fluctuate toward the entire study period (Figure 2). The pH values ranged from 3.9 to 5.3. The pH value of the peat increased by administering ameliorant material into peat. Soil fertility is inproved by increasing soil pH.

The highest pH values indicated in the treatment of dolomite while the lowest pH value is produced on Pugam treatment. An increase in pH due to the large donations of materials ameliorant OH^-. The high contribution of OH^- in the soil solution will increase the pH of the soil (Prasetyo and Gusmini, 2009).

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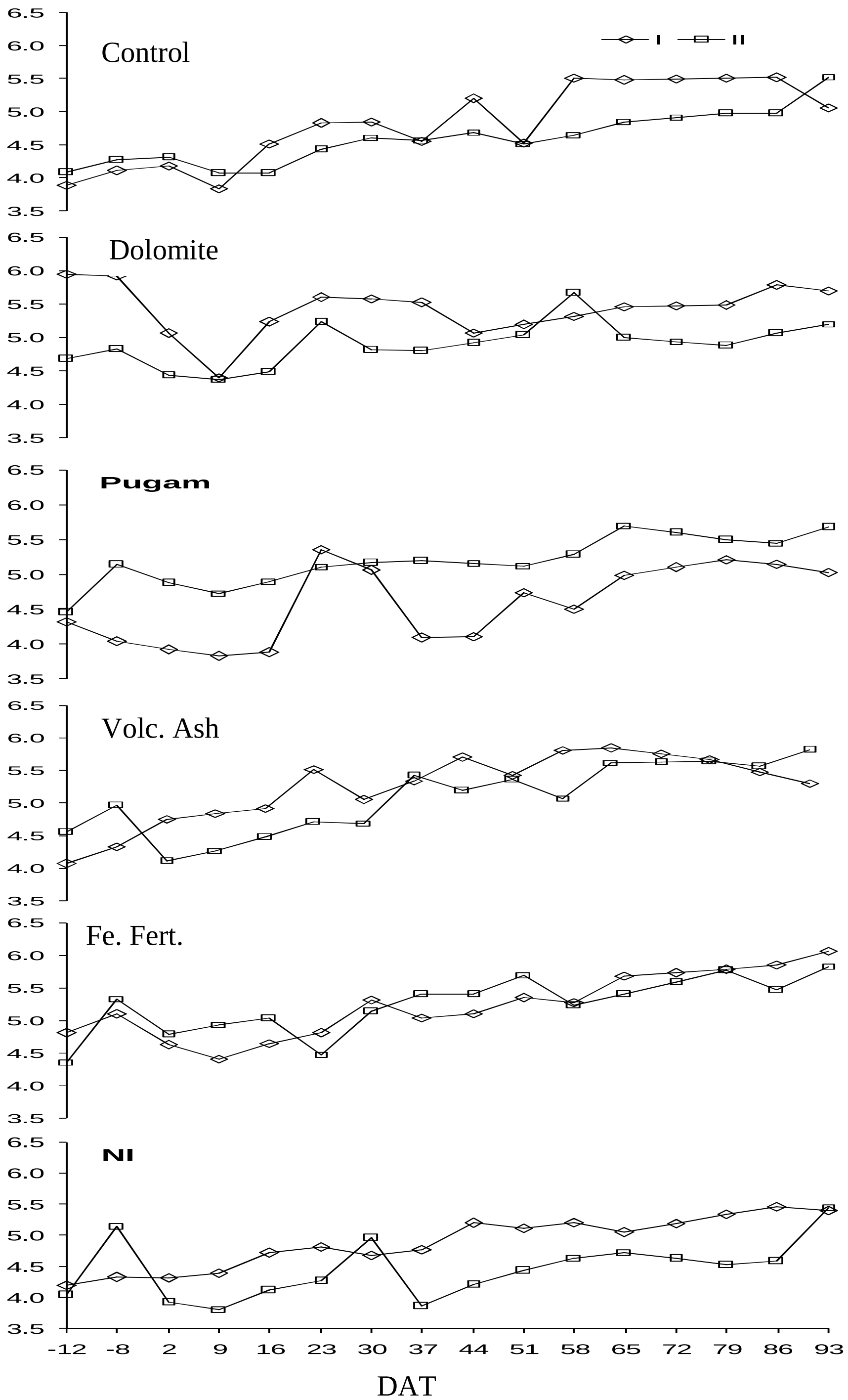

Figure 2. Changes in soil pH as affected by ameliorants. DAT=days after transplanting

Growth and Yield

Table 1 showed plant height and number of tiller at 16, 30, 44, 58, 72 and 86 days after transplanting (DAT). The number of tillers highest in old plants 86 DAT. The tiller numbers as high as 19 tillers were observed in the Pugam treatment, followed by control, Fe fertilizer, nitrification inhibitors, volcanic ash and dolomite treatments (as much as 17, 17, 16, 14 and 11 tillers, respectively)

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Table 1. Plant height and number of tiller as affected by treatments

Treatment	Day After Transplanting (DAT) 16	30	44	58	72	86
Plant height (cm)						
Control	33,5[a]	50,3[a]	66,5[a]	75,8[a]	90,4[a]	93,8[a]
Dolomite	29,8[a]	52,8[a]	66,3[a]	72,3[a]	88,3[a]	89,0[a]
Peat fertilizer	34,8[a]	52,8[a]	69,8[a]	80,3[a]	96,1[a]	95,5[a]
Volcanic ash	31,8[a]	52,3[a]	65,8[a]	78,3[a]	96,3[a]	94,5[a]
Fe fertilizer	32,0[a]	51,0[a]	65,8[a]	83,0[a]	87,4[a]	92,0[a]
NI	32,0[a]	52,3[a]	66,3[a]	76,3[a]	95,5[a]	93,8[a]
Number of tiller						
Control	3[a]	9[a]	15[ab]	16[a]	12[a]	17[a]
Dolomite	3[a]	10[a]	12[bc]	12[a]	11[a]	11[a]
Peat fertilizer	3[a]	9[a]	13[bc]	15[a]	18[a]	19[a]
Volcanic ash	3[a]	9[a]	11[c]	13[a]	12[a]	14[a]
Fe fertilizer	2[a]	7[a]	12[bc]	13[a]	14[a]	17[a]
NI	3[a]	13[a]	16[a]	14[a]	14[a]	16[a]

Values in the same column followed by the same letter are not significantly different at 5% *P*-level according to Duncan test

The percentage of filled grain in the treatment of volcanic ash was the highest (amount of 31%) compared to control (Table 2). The 1000-grain weight in Pugam was 3% higher than control treatment. Total biomass total and grain yield was highest in the treatment of NI (20% and 31% higher than controls). This results are in line with the report by Sabiham (2010). Supiandi (2010) reported that soil ameliorants are capable in fixing phenolic acid derivatives, such as ferulic, synapic, coumarik, and p-hydroxybenzoic acid is phytotoxic to rice, which are toxic to plant. Reduction of these acids lead to improved rice growth at treated plots.

Table 2. 1000-grain weight, % of filled grains, the number of productive tillers, heavy roots, straw weight, total biomass and grain yield as affected by soil ameliorants

Yield component	Treatment Control	Dolomite	Peat fertilizer	Volcanic ash	Fe fertilizer	NI
1000 grain weight (g)	23,9[a]	23,7[a]	24,7[a]	23,7[a]	24,3[a]	21,7[a]
% of filled grain	62,8[a]	71,5[a]	71,6[a]	82,7[a]	77,9[a]	73,6[a]
Number of productive tillers	14[a]	13[a]	15[a]	14[a]	15[a]	15[a]
Root weight (kg / m2)	0,10[a]	0,11[a]	0,11[a]	0,07[a]	0,10[a]	0,09[a]
Weight of hay (kg / m2)	0,46[a]	0,47[a]	0,53[a]	0,37[a]	0,44[a]	0,54[a]
Total biomass (kg / m2)	1,08[bc]	1,13[abc]	1,25[ab]	1,05[bc]	1,00[c]	1,30[a]
Grain yield (kg / m2)	0,49[ab]	0,54[ab]	0,60[ab]	0,60[ab]	0,44[b]	0,65[a]

Figures in the same column followed by the same letter are not significantly different means at 5% level according to Duncan test

Carbon Balance

The amount of C stored in plant biomass describes the amount of atmospheric CO_2 absorbed by plants. C content of the highest found in hay and grain, whereas the C organic content in the roots only about 7-13% of C organic biomass above. C content in the weeds also smaller than the rice crop (Table 2). This indicated that plants and weeds in agricultural land has the opportunity to absorb GHG emissions.

The highest carbon content in the biomass plant material indicated by NI treatment (Table 3). The highest carbon content in the grain is resulted by giving Pugam peat

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fertilizer. Low C content in the weeds was shown in the provision of volcanic ash. The highest carbon content was shown in Pugam treatment followed by volcanic ash, NI, dolomite, control and Fe fertilizer whose value were 5557; 5441; 5263; 4886; 4051-C and 4034 kg/ha, respectively. This indicates that administration of ameliorants can increase carbon uptake in plants and increase crop biomass.

Inorganic soil carbon-sequestration occurs through the conversion of carbon dioxide in the soil air into carbonic acid, and the re-precipitation as calcium carbonate and magnesium. Bicarbonate leaching into the soil layer is another mechanism for locking atmospheric carbon dioxide. Inorganic carbon, such as calcite and dolomite, formed about one third of the total soil carbon but is relatively stable and - except when applying chalk - not particularly influenced by tillage. Therefore, it is usually ignored when considering the effect of soil carbon in agricultural production and carbon sequestration. Approximately 50% of total anthropogenic CO_2-emissions of carbon taken up by natural sinks that soil, vegetation and sea (David, 2011).

Changes of soil tillage conventional to no-till farming, based on data for training on average in the US, will result in carbon sequestration clean soil on average of 337 kg C per hectare per year for the initial 20 years with a decline to near zero in year 20 below, and continued savings in CO_2 emissions because it reduces the use of fossil fuels (Gregg et al., 2003).

Table 3. The content of C in rice plants treated with ameliorant

Treatment	C-Organik Content			Total content of C-Organic	GWP (kg CO2-C/ha)	Net Carbon* (kg C/ha)
	Biomass	Grain	Weeds			
	---------------------kg-C/ha---------------------					
Control	853	3187	11,4	4051	7835	3785
Dolomite	921	3959	6,5	4886	8124	3238
Peat fertilizer	884	4672	1,2	5557	6996	1439
Volcanic ash	816	4445	0,8	5263	4551	-712
Fe fertilizer	827	3205	2,1	4034	6116	2082
NI	1049	4390	1,9	5441	7015	1574

* Net carbon = the amount of C is still emission after the C absorption by plants (vegetation);
Net carbon (kg C/ha) = GWP – Total content C-organic

Net carbon is the difference between the GWP of CO_2-C with total organic carbon content of the plant. GWP CO_2-C from highest to lowest indicated in the treatment of dolomite, control, NI, peat fertilizer, Fe fertilizer, volcanic ash which values were 8124, 7835, 7015, 6996, 6116 and 4551 kg CO_2-C/ha, respectively. The highest difference resulting from the reduction of the total carbon content found in the control treatment (GWP of 3785 kg-C/ha), followed by dolomite, Fe fertilizer, NI, volcanic ash and peat fertilizer. Smallest net-carbon means that the value of carbon uptake by plants produced the highest or lowest GWP. Minus net-balance values resulted in the provision of volcanic ash can be interpreted that the GHG emissions can be absorbed entirely. This proves that the use of volcanic ash in rice plants grown in peat is able to store more carbon than the amount of carbon released into the atmosphere and is able to suppress the emission of greenhouse gases.

CONCLUSIONS

It could be concluded that the net carbon was highest in control treatment (3785 kg-C/ha), followed dolomite, Fe fertilizer, NI (nitrification inhibitor), Pugam peat fertilizer (i.e 3238, 2082, 1574, and 1439 kg-C/ha, respectively). The lowest net carbon was from volcanic ash (-712 kg-C/ha).

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