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CHARACTERIZING AND ANALYZING *SONOR* SYSTEM IN PEATLANDS

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ABSTRACT

The research aimed to describe changing biomass during the burning process, to characterize the nutrient loss due to biomass burning, to analyze the financial loss of nutrient transfer, and to compare income of farmers. This research was conducted in the peatland typologies of B, C and D in Talang Sepucuk, OKI District, South Sumatra. The vegetation and paddy yields was recorded by squares method, i.e. 25 x 25 m at each study site, dried and weighed and analyzed in the laboratory. The nutrient transfer due to biomass burning was in range of US$ 3,844-3,970 ha/year. The income of farmers was very small US$ 829-912 ha/year, it was only about 22 % of the total financial loss of nutrient transfer. The remaining value (78 %) is beyond the capacity of farmers to harvest the peatland resources. This value is classified as one of the biggest negative impact of the *sonor* system to be paid by the all people. The government has to make the public policy by giving direct subsidy to farmers not to burn biomass with compensation of at least 2 (two) times of farmers income. If farmers continue to apply the *sonor* system by using fire, then there is very little opportunity for us to manage the nutrients loss due to biomass burning. The preventive and proactive approach is the best way how to manage the peatlands.

Keywords: Characterizing, analyzing, *sonor* system, peatlands

INTRODUCTION

Sonor (language of Palembang) means 'nalak', allowing or not taken care of. It is mostly done by local farmers in Kalimantan and South Sumatra. Now, this system has been adopted in peatlands, especially in Talang Sepucuk, OKI District. The sonor system is defined as a traditional paddy cultivation system in the peatlands, which is only carried out during the long dry season (at least 3-6 months of drought). The main purpose of the sonor system is generally used to reduce weeds (unwanted species of plants), to control pests and diseases, to stimulate the yields, to reduce crop residues, to clear land easily, cheaply, quickly and efficiently with minimal labor requirements (Page et al., 2010).

The main problem of the *sonor* system is to generate the smoke, to accelerate peat subsidence and to change ecosystem as well as to deplete all land resources.

These negative impacts are global and very poorly grouped into the environmental impact of biological, physical, chemical, social, economic, cultural and political (Armanto et al., 2013; Wildayana, 2014). The sonor system stimulates nutrients transfer into the atmosphere (Abram et al., 2014; Hribljan et al., 2015; Jauhiainen et al., 2012). The nutrients status in a land ecosystem is a measurable and tangible parameter in monetary value if the nutrient status is converted to fertilizers use (Armanto and Wildayana, 1998; Fisher et al. 2014).

Therefore, the research aimed to:

a) describe changing biomass during the burning process;
b) characterize the nutrient loss due to biomass burning;
c) analyze the financial loss of nutrient transfer;
d) compare farmer's income among three land typologies.

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MATERIALS AND METHODS

This research was conducted in peatlands Talang Sepucuk, OKI District, South Sumatra with a slope of 0-3 %. The weather condition at the research area was mild; relative humidity ranged 80-85 %. The winds were about 0-2 km/h, that making fires creep on the surface ground with average heights of fires were ranging 1.30-1.95 m. Three selected peatland typologies (B, C and D) are located in the area adjacent to one another with distance < 1,500 m. The natural vegetation data and paddy yields were recorded by making sample plots (squares method), i.e. 25 × 25 m at each land typology, dried and weighed and analyzed in the laboratory. Ash and the rest of the fire were collected by using the iron plate (tray), weighed and analyzed in a laboratory to determine the composition and amount of fire residual ash.

Nutrient transfer (loss) into the atmosphere in forms of smoke, gas emissions, carbon as well as small particles is calculated by comparing the composition of the biomass before burning and the biomass after burning (in the form of ash and fire residuals) with Formula 1. Financial loss of the nutrients transfer was based on fertilizer prices indirectly, namely the method of replacement cost (Wildayana and Armanto, 2009).

TA = NB - NU – NF (Formula 1)

Where:

TA : Nutrient transfer into the atmosphere, kg/ha

NB : Biomass nutrient amount before biomass burning, kg/ha

NU : Nutrient amount of unburned biomass after burning, kg/ha

NF : Nutrient amount in ash and firewood after burning, kg/ha.

RESULTS AND DISCUSSION

Biomass Components

Biomass (organic matters) in the research areas are located in or near the soil surface and are easy to recognize, namely: (1) natural vegetation or litter layers; (2) the peat layer consists of decomposed or partially decomposed, but recognizable and residuals of natural vegetation; (3) decayed wood, which consists of a matrix of residual lignin from woody materials in the ground or buried by the soil surface; (4) the humus layer, which is entirely decomposed and mixing with surface peats; (5) wood charcoal that are completely mixing with surface peats; and (6) the upper mineral soil horizon. The biomass serves as a major reserve for some macro and micro nutrients (Table 1).

Table 1. Characters of research areas

Land Typology	Vegetation	Fire quality	Biomass (tons/ha)
B	Heavy/thick shrubs	poorly burned	22.80
C	Local rubber mix	well burned	20.30
D	Secondary forest	well burned	22.00

Source: Field observation and measurements (2016).

Burning Processes

The biomass burning affected the nutrient cycling and the biological, chemical and physical characters of peats. Substantial amounts of C, N, S, and P are volatized to the air in the process of burning. Other macro nutrients are essentially important and critical nutrients in the wetland if biomass is burned. A transformation process of biomass burning is presented in Table 2.

At the moment most of the heat energy was released (the exothermic reaction) during the biomass burning, then the nutrients are transferred into the atmosphere. The heat energy in the burning process is a major cause of nutrient loss to the atmosphere. An average biomass contains 45 % for organic C, total N was 1.2 %, 0.3 % for total P, 0.2 % was total S, 1 % for total K, 0.3 % for total Ca, total Mg was 0.25 % and 0.02 % for the total Na.

The initial conditions of the research area had the amount of different biomass, thus the nutrients amount in biomass also varied. The Typology B has the highest biomass (22.80 tons/ha), therefore its nutrient contents were also much more compared to other sites. The Typology C had a low nutrient status because of its amount of biomass was also the lowest (20.30 tons/ha).

Table 2. Transformation processes of biomass burning

No	Temperature (°C)	Physical and chemical transformation processes
1	80-100	Free moisture evaporation happened
2	140-190	Lignin and hemicellulose components began degraded
3	< 200	The endothermic reaction occurred (reactions require heat absorption)
4	> 200	Decomposition of lignin and hemicellulose was accelerated
5	300	Cellulose undergo chemical dehydration and approximately 34 % of the total weight of biomass loss happen before the biomass reach 300 °C
6	> 300	The exothermic reaction dominated and biomass is ignited (reactions that produce heat)
7	500-600	Glowing burning occurs when oxygen is not excluded from the surface of the charcoal
8	> 1,100	Carbon is consumed on the surface as quickly as where charcoal is made
9	800-1,500	Ignition occurred and the temperature increased

Source: Field observation and measurements (2016); Raison et al. (1985).

Not all nutrients in biomass were completely burned during burning process. The unburned residual was accumulated or fixated with other nutrient on the soil surface and also left in the ash and firewood. Nutrient status at Typology D in both the biomass burned and unburned (in the ash and firewood) are the lowest compared with those in Typology B and Typology C. This is due to the quality of burning at Typology D was well burned, so most biomass was almost perfectly burned and the remaining in the form of ash. In other words, it can be concluded that it was not burning phase determining the amount of nutrient left unburned, but the quality of burning determines dominantly the amount of nutrient loss to the atmosphere.

Each nutrient has a threshold temperature; therefore the response of each nutrient is different. Volatilization of nutrients is determined as a definition of threshold temperature. The threshold temperature is classified into three groups, i.e. relatively insensitive, moderately sensitive and sensitive. Nutrients of C, N and S belong to sensitive nutrients due to their threshold temperature ranging 200 till 375 °C.

K and P are classified as moderately sensitive because their threshold temperatures are approximately 770 ^{o}C. On the other hand, Ca, Mn and Mg are called as relatively sensitive due to their threshold temperature of about 1,480 °C; 1,960 °C; and 1,100 °C respectively.

Due to the threshold temperatures of N, C, S, P, K and S are determined much lower than flaming temperature of wood as fuels (more 1,100 ^{o}C). Except P nutrient with glowing temperature of 600 ^{o}C, other nutrients (N, C, S, K and S) are easily volatized during burning of biomass (Hoelscher, 1997; Raison *et al.*, 1985). In addition, the high variation of nutrients loss is caused by the influence of different local weather at the time of the fire, and determined also by the quality of fire. Typology B with poor quality fire was less biomass burning compared to Typology C and Typology D with well burned quality of fire. Typology D shows the most biomass burning between the three land typologies.

Nutrients Balances

The most affected nutrient by the fire is C (9,603-9,952 kg/ha) and N (233.9-257.2 kg/ha) since both these nutrients are very vulnerable to fire. Nutrients transfer to the atmosphere is high which ranges from 94-97 % for C and N varied between 94-96 % of the original biomass reserves. This means nutrients are very susceptible to high temperatures and tend to quickly decompose and volatilized.

Nutrient N is bounded in the form of protein compounds in biomass, due to the fire; the protein compound was decomposed rapidly in total and most of the nutrients N becoming free into the atmosphere in gaseous form NO_2, NO_3, $NO_{x,}$ and others. The amount of total N volatilized during burning was directly proportional to the amount of biomass combusted.

Most of volatized N (over 95%) changed to the form of N_2 gas. This process does not occur at low temperatures because the biomass can be decomposed without volatilizing N. Thus N loss is not proportional with the biomass loss. Not volatized N still remains at the site in forms of unburnt fuel or available ammonium (NH_4-N) in the soils (Raison et al., 1985). There is a close relationship between C and N, thus the C/N will determine in regulating the decomposition levels of biomass. Nutrient balance by biomass burning (in kg/ha and %) is completely presented in Table 3.

Nutrient S loss by volatilization was intermediate and biomass burning caused to remove 31.46-34.19 kg/ha (69-74 %) of the S in biomass into the atmosphere. This means that nutrients S also is included to very vulnerable to high temperatures and tend to quickly decomposed and volatilized. Nutrient S fluctuates in the soils and it is parallel with inorganic N. Thus S nutrient is called as the second limiting factor in peatlands.

Nutrient P loss to the atmosphere ranged from 20-46 % or about 19.15-30.01 kg/ha of the total P was lost by non-particulate transfer when biomass (fuels) is totally consumed. Thus P nutrient in form available P is analyzed in the ash and the surface peats shortly after burning of peats.

Balances of Ca, Mg, and K play important role in determining of base saturation in soils and at the time they determine also to control values of soil acidity. Nutrient K loss varied 20-46 % (50.16-122.36 kg/ha) of the original biomass reserves. A large difference shown by Typology B (nutrient K: 50.16 kg/ha) tended to be much less than the loss of nutrient K at Typology C (80.39 kg/ha) and Typology D (122.36 kg/ha). The main cause of this variation was due to the quality of fire at Typology B was worse compared to those in Typology C and Typology D. Distribution of nutrient K into the atmosphere was limited to transport particles. So it can be said to be more perfect burning, the more particles are formed and flew into the atmosphere by bringing a number of nutrient K. It is estimated that the high amount of nutrient K loss happened because nutrient K was very easily separated from the complex sorption and easily volatilized into the air together with the particles of burning. This is supported by various studies that the burnt areas after more than a month, then it becomes more acidic soil (soil pH<4).

Increased soil acidity is due to missing or leached Ca and land dominated by cations, H, and Fe. Other nutrients such as Na (20-26 %), Ca (11-35 %), and Mg (20-41 %) showed quite high variation. These data are in line with the research (Hoelscher, 1997) that the amount lost through fires follow Nutrient N the following order: C, N> S> P, Na, Ca and Mg.

Financial Loss of Nutrient Transfer

Nutrient transfer was equalized on nutrient content in the fertilizers, i.e. compost (containing 200 % organic C), Urea (46 % N), SP36 (36 % P), Kieserite (22 % S and 16 % Mg), 96 % KCl (50 % K), lime CaO (71 % Ca), and Chilisalpeter (25 % Na). The financial analysis of nutrient transfer is presented in Table 4.

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Table 3. Nutrient balance by biomass burning in the *sonor* system (kg/ha)

Site	Nutrients							
	C	N	P	S	K	Ca	Mg	Na
Typology B (22.80 tons/ha), poorly burned								
NB	10,260 (100%)	273.6 (100%)	68.4 (100%)	45.6 (100%)	250.8 (100%)	68.4 (100%)	59.28 (100%)	4.56 (100%)
TA	9,644 (94%)	257.2 (94%)	19.15 (28%)	31.46 (69%)	50.16 (20%)	7.52 (11%)	11.86 (20%)	0.91 (20%)
NU	409.4 (3.99%)	8.07 (2.98%)	19.15 (46.80%)	8.60 (18.85%)	132 (52.65%)	39.58 (57.86%)	31.21 (52.64%)	2.28 (50.01%)
NF	206.2 (2.01%)	8.35 3.05%)	32.01 (25.5%)	5.54 (12.15%)	68.59 (27.35%)	17.56 (31.14%)	16.21 (27.36%)	1.37 (29.99%)
Typology C (20.30 tons/ha), well burned								
NB	9,135 (100%)	243.6 (100%)	60.9 (100%)	40.6 (100%)	223.3 (100%)	60.09 (100%)	50.75 (100%)	4.06 (100%)
TA	9,952 (97%)	233.9 (96%)	21.32 (35%)	29.64 (73%)	80.39 (36%)	17.12 (28%)	14.72 (29%)	0.97 (24%)
NU	242.1 (2.65%)	6.31 (2.59%)	26.91 (44.19%)	7.39 (18.20%)	100.2 (44.85%)	29.30 (48.11%)	24.41 (48.09%)	2.05 (50.60%)
NF	31.97 (0.35%)	3.44 (1.41%)	12.67 (20.81%)	3.57 (8.80%)	42.76 (19.15%)	14.55 (23.89%)	11.63 (22.91%)	1.03 (25.40%)
Typology D (22.00 tons/ha), well burned								
NB	9,900 (100%)	266.2 (100%)	68.2 (100%)	46.2 (100%)	266.2 (100%)	68.2 (100%)	57.2 (100%)	4.4 (100%)
TA	9,603 (97%)	252.89 (95%)	30.01 (44%)	34.19 (74%)	122.36 (46%)	23.87 (35%)	23.45 (41%)	1.14 (26%)
NU	232.65 (2.35%)	8.94 (3.35%)	24.82 (36.40%)	7.81 (16.91%)	93.49 (35.12%)	28.37 (41.60%)	27.50 (48.08%)	2.12 (48.21%)
NF	64.35 (0.65%)	4.39 (1.65%)	13.41 (19.60%)	4.58 (9.09%)	50.29 (18.88%)	15.96 (23.40%)	6.25 (10.92%)	1.14 (25.79%)

TA : *Nutrient transfer into the atmosphere, kg/ha), NB (Biomass nutrient amount before biomass burning, kg/ha*
NU: *Nutrient amount of unburned biomass after burning, kg/ha), NF (Nutrient amount in ash and firewood after burning, kg/ha*.

Table 4. Financial transfer nutrient equalization to fertilizer prices

Fertilizer	Typology B		Typology C		Typology D	
	kg/ha	Rp/ha (×1000)	kg/ha	Rp/ha (×1000)	kg/ha	Rp/ha (×1000)
CO	19,288	9,644	19,904	9,952	19,206	9,603
UR	559	1,006	508.48	915	550	990
SP	53	38,576	59	39,808	84	38,412
KI	143	315	135	296	155	342
KCl	100	266	161	426	245	649
LI	11	6	24	15	34	20
KI	74	163	92	202	147	322
CH	4	7	4	8	5	9
Total	20,232	49,983	20,887	51,622	20,424	50,347

CO *(Compos),* UR *(Urea),* SP *(SP36),* KI *(Kieserite),* LI *(Lime CaO),* KCl *(Potassium chloride),* CH *(Chilisalpeter)*
Source : Primary data calculation (2016).

The fertilizer prices are Rp 500/kg for compost; Rp 1,800/kg for Urea; Rp 2,300/kg for NPK fertilizer; Rp 1,400/kg for ZA fertilizer; Rp 2,000/kg for SP36 fertilizer; Other fertilizers do not belong to the subsidized fertilizers, i.e. Rp 2,650/kg for KCl (MOP), Rp 600/kg for lime CaO, Rp 2,200/kg for Kieserite and Rp 2,000/kg for Chilisalpeter.

The nutrient transfer due to biomass burning was in range of Rp 49.98-51.62 million/ha/year. This calculation was based only on a small part of biomass burning and will be even greater if the economy valuation is analyzed by involving other benefits (direct and indirect benefits, option and rewards benefits and existence benefits).

Farmer's Income and Financial Loss of Nutrient Transfer

The sonor system paddy gave the farmer's income Rp 10.78-11.85 million/ha/year. The value of B/C was in ranges from 0.66-069. It means the sonor system is still slightly profitable because the value of B/C is > 0. R/C ranged from 1.66-1.69 and still feasible to be developed (but not from the ecological aspect) because R/C was > 1 (Table 5).

If the farmer's income is compared with financial loss of nutrient transfer, the farmer's income in the sonor system was very small (only about 7 % of the total financial loss of nutrient transfer). The remaining value (93 %) is beyond the capacity of farmers to harvest natural resources and this value (93 %) is classified as one of the biggest negative impact of the sonor system to be paid by the all people (Table 6).

Table 5. Farming analyses of Ciherang paddy variety in the dry season

Parameter	Typology B	Typology C	Typology D
Yields (GKG tons/ha/year)	3.61	3.84	3.93
The total cost of farm (Mill. Rp/ha/year)	5.47	5.69	5.84
Revenue (Rp million/ha/year)	16.25	17.28	17.69
Income (Rp million/ha/year)	10.78	11.59	11.85
B/C	0.66	0.69	0.68
R/C	1.66	1.69	1.68

GKG (Milled Dry Paddy) with field price Rp 4,500/kg
Source: Primary data calculation (2016).

Table 6. Farmer's income and financial loss of nutrient transfer

Land Typology	Farmer's Income (Rp million/ha/year)	Nutrient Transfer (Rp million/ha/year)	Income and Nutrient Transfer Ratio
B	10.78	49.98	0.22 (21.57 %)
C	11.59	51.62	0.22 (22.45 %)
D	11.85	50.35	0.24 (23.54 %)
Average	11.41	50.65	0.23 (22.53 %)

Source: Primary data calculation (2016).

The government must intervene to make the public policy by giving direct subsidy to farmers not to burn biomass in the sonor system with compensation of at least 2 (two) times of farmers benefit from the sonor system (around Rp 7.66 million/ha/year). If farmers continue to apply the sonor system by using fire, then there is very little opportunity for us to manage the nutrients loss due to biomass burning. The preventive and proactive approach is the best way how to manage the land resources.

CONCLUSIONS

The nutrient transfer due to biomass burning was in range of US$ 3,844-3,970 ha/year (or Rp 49.98-51.62 million/ha/year). The farmer's income of the sonor system was very small US$ 829-912 ha/year (Rp 10.78-11.85 million/ha/year), it was only about 22 % of the total financial loss of nutrient transfer). The remaining value (78 %) is beyond the capacity of farmers to harvest natural resources. This value (78 %) is classified as one of the biggest negative impact of the sonor system to be paid by the all people.

The government must intervene to make the public policy by giving direct subsidy to farmers not to burn biomass in the *sonor* system with compensation of at least 2 (two) times of farmers income from the *sonor* system (around US$ 1,755 ha/year or Rp 22.82 million/ha/year). If farmers continue to apply the *sonor* system by using fire, then there is very little opportunity for us to manage the nutrients loss due to biomass burning. The preventive and proactive approach is the best way how to manage the peatlands.

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