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ORIGINAL ARTICLE

Impact on Peatland Canal Blocking of Soil Properties in The EKS PLG Million Ha of Central Kalimantan Province

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ABSTRACT

Peatland improvements can be done by blocking canals in Ex-PLG million ha in order to keep the peat moist and improve peatland ecosystems. Research uses vegetation analysis method and soil samples taken through purposive sampling. Blocking canal construction on burning peatlands has led to succession and secondary forests. Canal blocking development has significantly improved soil moisture properties (51%), soil permeability (90%), Cation Exchange Capacity (369%), Organic C (845%), Soil Nitrogen (271%), total microorganisms (196%), number of fungi (464%) and solvent bacteria P (104%).

Key words : Land fire, peatland, canal blocking, soil properties

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INTRODUCTION

Peatland are forest formations that form on peat soils. Peat soil is a soil with an organic material content of more than 20% or organic C> 12% (sand texture) or organic material more than 30% (organic C> 18%) (clay texture). Layers containing organic material more than 40 cm peat soils have acid properties due to the presence of organic acids produced by imperfect decomposition of plant residues. Peat soils are generally formed in anaerobic soil, flooded soil, and soil that have high salinity. The accumulation of hundreds of years of this organic material forms peatlands. The nature of this acid limits for the growth of certain species of flora and fauna in this region. Peatlands are overgrown with trees formed on peat forests. (Hardjowigeno 2003; Soerianegara and Indrawan 2005). The rate of peat soil formation is from 0.5 to 1.0 mm / year (Wibowo 2009, Andriesse 1988) and 0.4-2.2 mm / year (Purwanto and Gintings 2011).

Conversion of peatland into agricultural land has occurred on a million ha of land in Central Kalimantan Province. Activities undertaken are cutting tree and constructing channels or canals. The impact of these activities resulted in nearly 97% of the peatlands burned in 1997. (Simbolon 2004; Mawardi 2007). Based on a satelite image analysis on an area of 2.5 million ha located in ex-mega rice project in Palangkaraya, Central Kalimantan, before and after the fires of 1997 it was found that 32% (0.75 million ha) of the area has been burnt in which 0.73 million ha of them (91.5%) are peatlands (Page et al 2002). Fires on peat soil cause a decrease in thickness of peat soil (subsidence), damage to physical properties, kima and biology (Pandjaitan and Hardjoamidjojo 1999; Wibowo 2009; Purwanto and Gintings 2011).

Research result indicate that peat soil burning ex PLG million ha have succeeded secondary forest in which there are 17 species of tree with plant species in tree level are: Geronggang (Cratoxylon arborescens (Vahl) Blume), Tumih (Combretocarpus rotundatus (Miq.) Danser), Hangkang (Palaquium leiocarpum), Nyatoh (Palaquium rostratum (Miq.) Burck), Jelutung (Dyera costulata Hook. F), Meranti (Shorea sp). and so forth (Wasis and Mulyana 2009; Saharjo et al 2011). Peat soil improvements can be blocked by canals in order to keep the peat moisture (Saharjo et al 2011).

The important thing to examine is the change of canal blocking impact on soil properties. The objectives of the study is to observe and to measure the impact of blocking canals on the properties of burnt peatlands in the Ex-Mega Plot Million in Central Kalimantan Province

MATERIAL AND METHODS

Place and Time of The Research

The research were carried out in ex-PLG million ha especially in various types of vegetation from several stages of growth such as trees, poles, stakes, burned down plants in 10 years ago and not having much human intervention, including dams that have been dammed for suppressing the rate of destruction that until now has not been known certain effectiveness scientifically.

Tools and Materials

The research tool used is divided into two groups: data collection tools in the field and nutrient analysis tools in the laboratory. The data retrieval equipment in the field is ring samples, chain saw, soil drill, camera, hoe, machetes, meter, plastic bag.

The research objects are samples of intact soil and composite soil samples derived from Ex-PLG of million ha in Central Kalimantan Province

Research procedure

Making Vegetation Analysis Plot

.Measurements were conducted in each plot of 20 meters x 20 meters for trees, sub-plots measuring 10 meters x 10 meters for the standing stock (mangrove forest), sub-plot measuring 5 meters x 5 meters for saplings, lianas, epiphytes and sub- meter x 2 meters for saplings and plants located under water with sequence of observations regarding observation team (Soerianegara and Indrawan 2005). The measurement results are recorded in tally sheets that have been distinguished in each plot size.

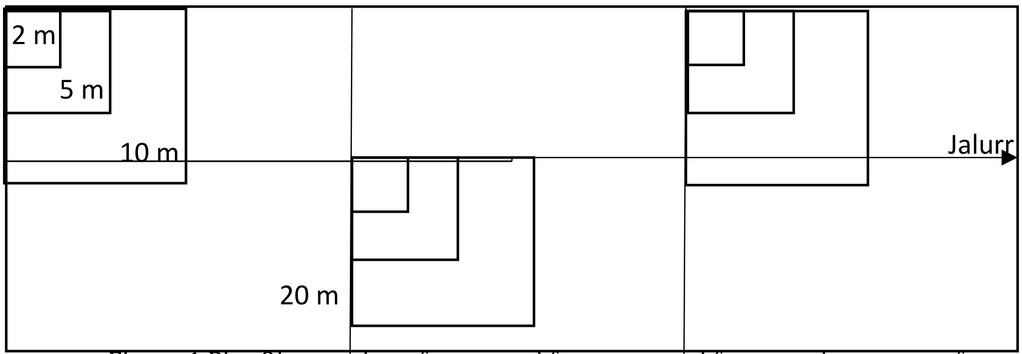

Figure 1 Plot Observation of protected forest, coastal forest and mangrove forest

Data analysis.

Calculation of vegetation analyzes conducted using certain parameters to determine the composition and structure of secondary forest stands at blocking canal sites include relative density, relative frequency, relative dominance and importantance value index (Soerianegara and Indrawan 2005):

Soil Sampling.

Soil sampling is done by purposive sampling on agricultural area and secondary forest. The research was conducted on three plots in secondary forest and agricultural area with each size 20 m x 20 m (0.04 ha). In the plot, there are three subplots with the size of 1m x 1m placed randomly for sampling the soil. Then the soil sample is composite (Wasis 2012)

Soil sampling for the chemical properties and biological properties of the soil is taken evenly on the soil surface of 0-20 cm deep. Taking soil is done in compose level as much as 1 kg. Sampling soil for physical properties was done at ground depth of 0 - 20 cm. Soil intake is done intactly by using ring sample with diameter of 7 cm and with the height of 5 cm (Wasis 2012).

Soil Analysis.

The soil taken from the field is then analyzed in the laboratory. Soil analysis for physical properties of bulk density, porosity, available water and permeability, for analysing chemical properties of pH, CEC, c-organic, nitrogen, and calcium. Soil biological properties analyzed total microorganisms, P dissolving bacteria, total fungi, and respiration.

The location of sample in secondary forest and agricultural area is located side by side. Therefore, the difference of soil type, topography, climate and other is relatively assumed same.

Data analysis.

Data for soil analysis from the location of Ex-PLG million ha were then analyzed statistically by using average difference test at 95% confidence interval (Mattjik and Sumertajaya, 2013; Stell and Torries 1991; Wibisono, 2009). The variables for soil physical properties are bulk density, porosity, water availabality and permeability. Variables for soil chemical properties are pH, CEC, C-organic, nitrogen, and calcium and variables for soil biological properties are total microorganisms, P dissolving bacteria, total fungi and respiration.

RESULTS AND DISCUSSION

Secondary forest vegetation structure

Based on the analysis of tree level vegetation on secondary forest, there are 4 types of trees which are Geronggang (*Cratoxylon arborescens*), Tumih (*Combretocarpus rotundatus*), Acacia (*Acacia crassicarpa*) and jelly (Garcinia sp) with a density of 5-15 Individuals / ha. Based on the analysis of vegetation for pole level in secondary forest, there are 4 types which are Geronggang (*Cratoxylon arborescens*), Tumih (*Combretocarpus rotundatus*), Acacia (Acacia crassicarpa) and mahambung (Garcinia sp) with a density of 200 - 380 Individuals / ha. Based on the results of vegetation analysis for the level of stake in the secondary forest, there are 8 types which are Acacia (*Acacia crassicarpa*), shorea (Shorea sp), cempedak, riding (*Cratoxylon arborescens*), crocodile (Garcinia sp) , manga (*Mangifera indica*), tatumbu (*Syzygium havilandii*) and telayar (Diospyros sp). Value of vegetation analysis obtained density equal to 80 - 4160 Individual / ha. Based on the results of vegetation analysis for the seedling level in secondary forest, there are 8 types which are bintang (Serissa japonica), riding (*Cratoxylon arborescens*), kramonting (Rhodomyrtus tomentosa), crown (Garcinia sp) , matondang (Cerbora sp), sesendokan (*Plantago major*), tatumbu (Syzygium havilandii) and telayar (Diospyros sp). The value of vegetation analysis obtained density of 1000 - 28500 Individual / ha. Based on the results of vegetation analysis for the lower plants in the secondary forest, there are 8 types which are rage (*Debregeasia langifolia*), hawuk (Acalypha siamensis), pakis (Diplazium esculentum), kelakai (*Stenochlaena palustris*) , purun tikus (*Eleocharis duicis*), purun danau (*Lepironia articulata*), dutch grass (*Pennesitum purpureum*) and grass rage (Eluisine indica). The value of vegetation analysis obtained density of 1000 - 49000 Individual / ha

Canal Blocking impact on soil properties

Physical Properties of the Soil

The result of field observation on agricultural land shows that burnt peat soil has caused the subsidence of peat soil 10-30 cm, the death of under plants (pakis, kelakai, grass and others) and death of soil animal (ant, spider, grasshopper, termites and others.

Physical properties of soil analyzed were bulk density, porosity, water availability and permeability. The analysis result of soil physical characteristic can be seen in Table 1. The result of statistical analysis for the mean difference test to the impact of canal blocking development from agricultural area to secondary forest shows that there has been significate difference in water availability and permeability, whereas bulk density and porosity not differs significantly.

Table 1. Impact of channel blocking on soil physical properties

No.	Physical properties	Non Canal Blocking (Agricultural area)	Blocking Channels (Secondary Forest)	Change
1.	Bulk density (gram/cm^3)	1,07 ± 0,23 ^{tn}	0,66 ± 0,23	- 0,41 (38%)
2.	porosity (%)	59,85 ± 8,60 ^{tn}	73,48 ± 2,56	+13,63(23%)
3.	Available water (%)	10,76 ± 1,42 *	16,27 ± 0,61	+5,51 (51%)
4.	Permeability (cm/hour)	15,46 ± 2,37 *	29,35 ± 1,78	+13,89(90%)

** : highly significant at 99 % confidence interval

* : significant at 95 % confidence interval

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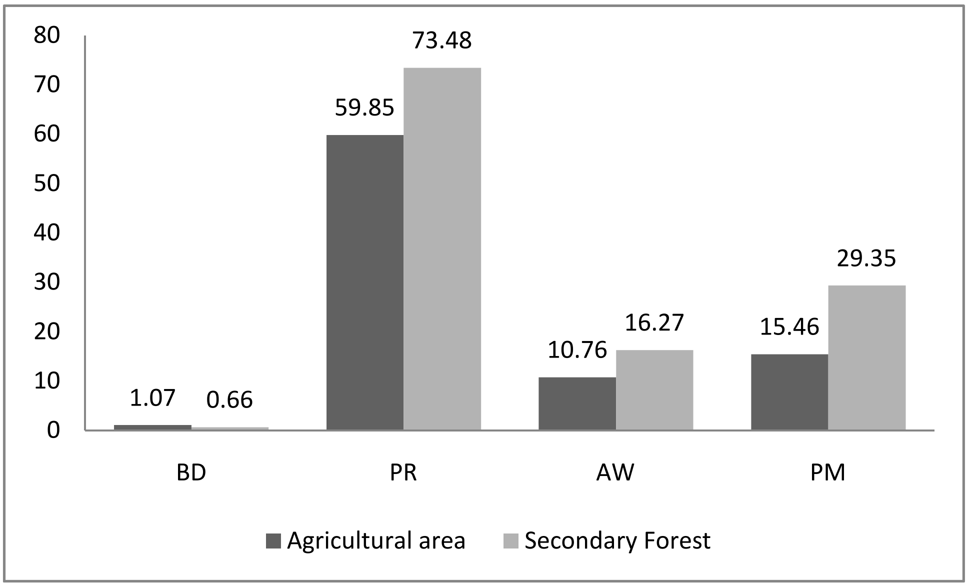


Description : BD(Bulk Density : gram/cm^3), PR (Porosiys : %), AT (Available water : %) PM (Permeability : cm/hour)

Figure 2 The change of soil physical properties on agricultural land and secondary forest

Canal blocking developing activities have led to a decrease in bulk density and an increase in porosity. Bulk density decreased by 0.41 gram / cm3 and porosity increased of 13.63%. The decrease in soil density was due to an increase in organic matter from forest litter and improved peat soil conditions. Besides, the impact of decreasing peat density has led to soil pore repair. The result of the research shows there has also been improvement for soil pore.

The impact of canal blocking the development has been improved water system in which it can be seen that the increase in ground water. This condition indicates that peat soils have begun to store better water. Construction of the canal will cause the peat soil to become dry. Excessive drainage causes the peat soil to dry and unable to absorb water due to the irreversible nature of peat soil (Pandjaitan and Hardjoamidjojo 1999)

Soil damage caused by logging and heavy equipment usage is 5.74% (35%). This is because the fraction of clay and organic matter on the soil surface is decreased due to peeling of the top layer by heavy equipment and soil erosion.

The results of this study indicate that the construction of canals (canal blocking) has led to improved soil physical properties. The most important physical properties of the soil in relation to water governance are water availability and permeability. According to research results of Hendrayanto et al (2001), surface runoff / flood (decrease in water system) was due to decreased soil infiltration capacity and not sufficient quality of land cover. In addition, Aminudin (2012) has found that natural forest clearance has become a planting path causing a decrease in permeability of 2.92 cm / h, a decrease of 2.93% porosity, 3.22% reduction in water availability and an increase in bulk density of 0, 08 gram / cm3.

Canal blocking and the presence of secondary forests will decrease surface runoff and soil erosion. The existence of vegetation cover such as a thick secondary forest can eliminate the impact of rainfall intensity on erosion. Vegetation covering the soil surface will tightly protect the soil from falling rainwater and will slow down runoff and it also transports soil particles. Cultivated plant species play an important role in erosion prevention (Arsyad 2006).

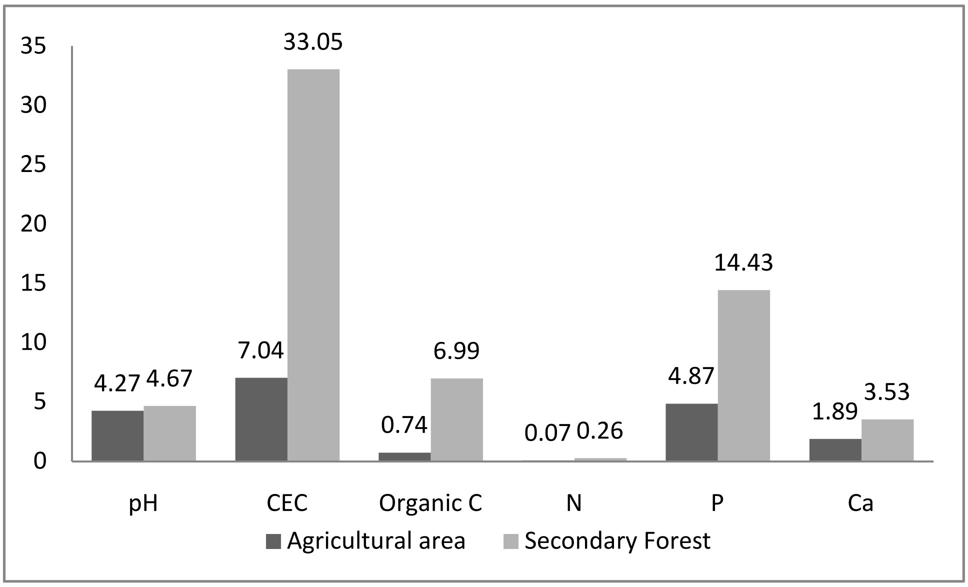
Properties of Soil Chemistry

The soil chemistry properties analyzed were pH, CEC, C-Organic, Nitrogen, Phosphor and Calcium. The results of soil chemical properties analysis are presented in Table 2. Based on the statistical analysis using the average difference test, it is found that the cation exchange capacity (CEC) and C-organic influence significantly while nitrogen (N) has highly significant influence. As for soil pH, phosphor and calcium are not significant.

Table 2. Impact of channel blocking on soil chemical properties

No.	Chemical properties	Non Canal Blocking (Agricultural area)	Canal Blocking (Secondary Forest)	Change
1.	pH	4,27 ± 0,06 tn	4,67 ± 0,25	+ 0,40 (9%)
2.	CEC (me/100 gram)	7,04 ± 2,02 *	33,05 ± 7,44	+ 26,01 (369%)
3.	C-Organik (%)	0,74 ± 0,31 *	6,99 ± 1,98	+ 6,25 (845%)
4.	Nitrogen (N) (%)	0,07 ± 0,02 **	0,26 ± 0,03	+0,19 (271%)
5.	Phosphorus (P) (ppm)	4,87 ± 1,72 tn	14,43 ± 6,10	+9,56 (196%)
6.	Calcium (me/100 gram)	1,89 ± 0,44 tn	3,53 ± 0,55	+1,64 (87%)

** : highly significant at 99 % confidence interval
* : significant at 95 % confidence interval



Description : pH (pH), CEC (cation exchange capacity : me/100 gram), organic C (%), N (Nitrogen : %), P (Phosphorus : ppm), Ca (calcium : me/100 g)

Figure 3 The change of soil chemistry properties on agricultural land and secondary forest

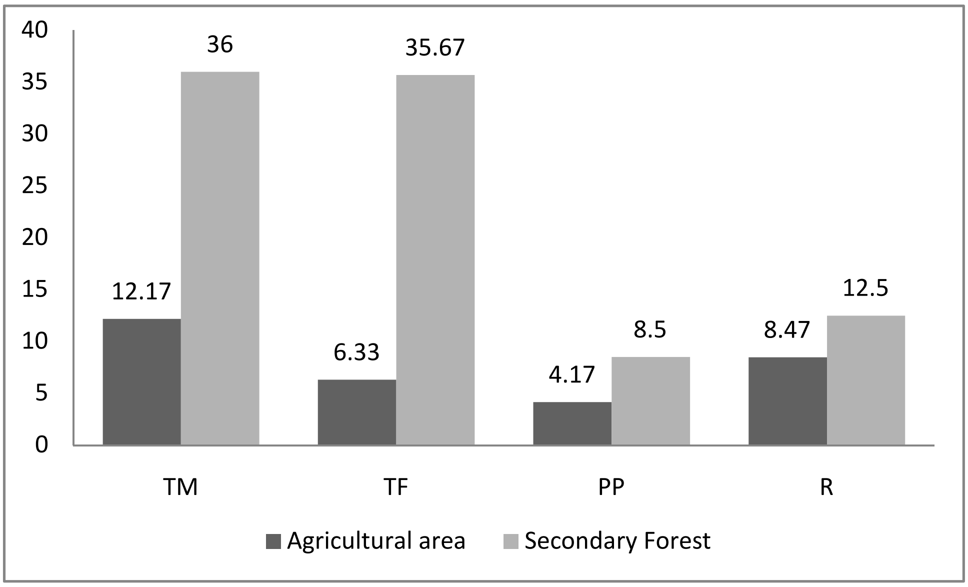
The canal construction has improved the peat chemistry properties of real soil such as CEC, soil organic and soil nitrogen. Improvement of soil chemical properties is caused by canal blocking causing wet peat soil and secondary forest growth. The existence of secondary forest will cause the cycle of substance/matter and cycle of energy becoming active and life process flowing towards the better stage.
Damage to peat soils and natural forests due to tree logging and land fires will result in loss of natural forest biomass, peat biomass, peat subsidence, the loss of soil flora and fauna, the destruction of water system function, the release of carbon to air and the loss of nutrients, especially organic matter. The decline in organic material due to supply of twigs, leaves, litter and organic matter to the soil by natural forest vegetation will be decreased and even lost. Declining the supply of organic matter to the ground floor of the forest will certainly result in decreasing soil nutrient content such as organic C, N, P and Ca. Logging of natural forest has led to the impoverishment of nutrients N, P, K, Ca and Mg of land (Wahyudi 2011; Aminudin 2012) and Indrawan (2003) suggests that logging activities in natural forests in the first rotation will increase the logging period in the second rotation.
One form of soil damage is the loss or the decrease of organic matter faster than its addition to the topsoil. The imbalance between the input of organic matter with the loss occurring through decomposition and land fires will have an effect on the decrease in soil organic matter content in the soil. The decline of soil organic matter has an impact on long-term sustainability because organic matter plays an important role for tree growth through its effects on physical properties, chemical properties and soil biological properties. These factors will in turn affect the soil structure, infiltration rate, water holding capacity, the

availability of plant nutrients and the rate of mineralization. In treated agricultural land, top soil (0 - 30 cm) loses 20-60% of the carbon present in natural forest vegetation (Wasis 2006; Wasis 2012).
Improving the chemical properties of burning peat soils in addition to blocking canals can be done by fertilizer, lime, compost and green manure so that the loss of organic matter (subsidence) burnt as thick as 10-30 cm can be replaced (Wasis 2003; Wasis 2012).
Properties of Soil Biology
The biological properties analyzed were total microorganisms, total fungi, P dissolving bacteria and respiration. The result of soil physical properties analysis can be seen in Table 3. The result of statistical analysis of the mean difference test indicates the total of microorganism and P dissolving bacteria. The different puncture is very significant, the total soil fungi have real effect while the soil respiration is not significantly different.

Table 3. Conditions of soil biological properties in agricultural and secondary forest areas

No.	Biology Properties	Non Canal Blocking (Agricultural area)	Canal Blocking (Secondary Forest)	Change
1.	Total microorganism (x 10^6 cpu)	12,17 ± 5,48 **	36,00 ± 7,00	+ 23,83 (196%)
2.	Total fungi (x 10^4 cpu)	6,33 ± 1,52 *	35,67 ± 12,77	+ 29,34 (464%)
3.	P dissolving bacteria (x 10^3 cpu)	4,17 ± 1,61 **	8,50 ± 1,80	+4,33 (104%)
4.	Respiration (mgC-CO_2/kg soil /day)	8,47 ± 0,72 tn	12,50 ± 2,59	+4,03 (48%)

** : highly significant at 99 % confidence interval
* : significant at 95 % confidence interval



Description : TM (total microorganism : x 10^6 cpu) , TF (total fungi : x 10^4 cpu), PP :(phosphorus dissolving bacteria: x 10^3 cpu), R (respiration : mgC-CO_2/kg soil/ day)
Figure 4 Changes in soil biological properties in agricultural and secondary forest areas

Canal blocking has resulted in significant improvement of soil biological properties such as total microorganisms by 23,83 x 10^6 spk (196%), total fungi 29,34 x 10^4 cpu (464%), and P disollving bacteria of 4.33 x 10 3 cpu (104%). These results prove that blocking canals have improved the biological properties of the soil. Soil microorganisms function to maintain soil fertility in which it is proven by the high content of nutrients in secondary forests. According to Subba Rao (1986), soil microorganisms are necessary to maintain soil fertility and play an important role in the nutrition cycle. Forest soil

improvement can be accomplished by inoculation of VA-mycorrhizal and Rhizobium inoculation increasing the growth (Rumondang and Setiadi 2011; Tuheteru and Husna 2011)
The restoration of damaged soil in Eks PLG million ha can be done by giving compost or manure, microchaniosmic inoculation (mycorrhiza) as well as planting endemic type of vegetation. According to Nguyen and Klinnert (2001), the provision of organic fertilizer is highly recommended to maintain crop productivity and soil fertility. The addition of organic matter in the soil is a potential source of N, P and S elements for plant's growth. The decomposition of microbiological organic matter is an important step to release nutrient bonds. Therefore, it becomes a usable form to plants (Kumada 1987). The inhibition of mycorrhizal inoculation is necessary to promote plant growth and nutrient conservation (Rumondang and Setiadi, 2011).

CONCLUSION

Blocking canal construction on burning peatlands has led to succession and secondary forests. Blocking channel has significantly improved soil moisture properties (51%), soil permeability (90%), Cation Exchange Capacity (369%), Organic C (845%), Soil Nitrogen (271%), total microorganisms (196%), total fungi (464%) and P dissolving bacteria (104%).

REFERENCES

1. Aminudin I. 2012. The Development Stand on Production Natural Forest in TPTI Silvicultural System.. Disertation Sekolah Pascasarjana Institut Pertanian Bogor.
2. Andriesse J. P. 1988. Nature and Management of Tropical Peat Soil. Soil Researches Management and Conservation Service. FAO Land and Water Development Division. Rome
3. Arsyad S. 2006. Soil and Water Conservation. IPB Press. Bogor
4. Bapenas. 2003. Strategy and Action Plan for Indonesian Biodiversity 2003-2020. IBSAP Documen Regional. Goverment Republik Indonesia.
5. Binkley D. 1987. Forest Nutrition Management. Duke University, Durham, North Carolina. USA.
6. Barrow CJ. 1991. Land Degradation. Cambridge : Cambridge University Press.
7. Evans J. 2000. Sustainaibility of productivity in successive rotations. Proc. of International Conference on Timber Plantation Development. November 7-9, Manila , Phillipines.
8. Hardjowigeno S. (2003). Science of Soil. Akademia Akapressindo. Jakarta
9. Mattjik, A.A. and Sumertajaya, I.M. (2013). Experimental Design with SAS Applications and Minitab. IPB Press. Bogor.
10. Mawardi I. 2007. Rehabilitation and Revitalization of Peatland Development Projects in Central Kalimantan. Jurnal Teknologi Lingkungan 8(3) : 287-297.
11. Kumada, K. 1987. Chemistry of Soil Organic Matter. Japan Scientific Societies Press. Tokyo.
12. Mulyanto L. and Jaya INS. 2004. Analisis spatial degradasi hutan dan deforestasi : Studi kasus di PT Duta Maju Timber, Sumatera Barat. Jurnal Manajemen Hutan Tropika 10(1) : 29-42.
13. Nguyen TD,and Klinnert C. 2001. Problem with and local solution for organic matter management in Vietnam. Kluwer Academic Publishers, Printed in the Netherlands. *Nutrient Cycling in Agroecosystems 61 : 89 - 91.*
14. Ohorella S *et al*. 2011. Efektivitas kelembagaan lokal dalam pengelolaan sumber daya alam hutan pada masyarakat Rumahkay di Seram Bagian Barat, Maluku. *Jurnal Manajemen Hutan Tropika 17 (2) : 49 - 55*
15. Oldeman, L. R. 1992. The Global Extent of Soil Degradation. Di dalam : Greenland, DJ Szabole I Editor. Soil Resiliense and Sustainable Land Use. Procedings of a Symposium of Sustainable Land Use. Budapest : CAB International 99 – 105.
16. Page, S., Siegert, F., Rieley, J.O., Boehmn, H.D.V., Jaya, A dan Limin, S. 2002. The amount of carbon released from peat and forest fire in Indonesia during 1997. Nature. Vol.42: 61-65
17. Pandjaitan N. P and Hardjoamidjojo. 1999. Study of Physical Nature of Peatland in Relation to drainage for Agricultural land. Buletin Keteknikan Pertanian 13 (3) : 87 – 96
18. Purwanto I. and Gintings A. N. 2011. Indonesia's Peatland Potential to Store Carbon. Hidrolitan 2(1) : 1-10.
19. Rahim SE. 2006. Control of Soil Erosion in the Framework of Environmental Conservation. PT Bumi Aksara. Jakarta.
20. Soerianegara I, Indrawan A. 2005. Indonesian forest ecology. Department of Forest Management, Faculty of Forestry IPB, Bogor.
21. Stell, R. G. D. and Torries JH. (1991). Statistical Principles and Procedures, A Biometric Approach. PT Gramedia Pustaka Utama Jakarta , pp 149-167
22. Tuheteru FD and Husna. 2011. Growth and Biomass Albizia saponaria on Local Arbuscular Mycorrhizae Fungi from Southeast Sulawesi.. Journal of tropical Silviculture Science and Technology *2 (3) : 143-148.*
23. Rumondang J, and Setiadi Y. 2011. Evaluation of Arbuscula Mycorrhizae Fungi (AMF) Application to Teak (Tectona grandis Linn. F) Seedling and Its Growth Responses in Nursery. Journal of tropical Silviculture Science and Technology *2 (3) : 194-197.*
24. Saharjo BH and Wasis B. 2006. Do we need to protect our natural resources? . Advances in Earth Science 21 (2): 178-182.

25. Saharjo B.H., Wasis B and Mulyana D. 2011. Canal Blocking of Burn Peat Swamp Forest and It's Future. 5 th International Wildland Fire Conference : Poster Session, South Africa.
26. Simbolon H. 2004. Early Process of Recovery at Peat Swamp Forest at Kelampangan – Central Kalimantan after Forest Fire December 1997 and September 2002. Berita Biologi 7 (3) 145-154.
27. Subba Rao, N. S. 1986. Soil Microorganism and Plant Growth. Oxford and Publishing Co. New Delhi.
28. Wasis B. 2006. Comporison of Site Quality between First Rotation and Second Rotation *Acacia mangium* Plantation Forest (A Case Study in Industrial Plantation Forest of PT Musi Hutan Persada, South Sumatra Province). Disertation : Bogor Agricultural University (IPB). Bogor
29. Wasis B. 2012. Soil Properties in Natural Forest Destruction and Conversion to Agricultural Land in Gunung Leuser National Park, North Sumatera Province. JMHT XVIII(3) : 206-212
30. Wasis B and Mulyana D. 2009. Carbon Content at Several Vegetation Type in Ex-PLG Million ha after 10 Years Burnt. proceedings of IPB research seminar. Bogor
31. Whitmore TC. 1975. Tropical Rain Forest of The Far East. Clarendom Press. Oxford.
32. Wibowo A. 2009. Role of Peatland in Global Climate Change. Teknologi Hutan Tanaman 2(1) 19-28.
33. Wibisono, Y. (2009). Statistics Method. Gadjah Mada University Press. Yokyakarta. pp 529-603