# Physical and Chemical Peatsoil Properties Assessment in Kampar Peninsular Region, Sumatera, Indonesia

**Budi Darmawan[1], Yusni Ikhwan Siregar[2], Sukendi[3], Siti Zahrah[4]**

[1]Student Department of Environmental Science, Riau University, Indonesia

[2]Lecturer, Environmental Science Department, Riau University, Indonesia

[3]Lecturer, Environmental Science Department, Riau University, Indonesia

[4]Lecturer, Agriculture Departments, Islamic University of Riau, Indonesia

**Abstract:** ***Forests and peat fires prior to agriculture use has become a perennial problem in Indonesia, especially in the last 20 years during the dry season. Most of that smoke originates from human activity - land use and land cover change (LULCC) i.e. illegal forests and peat land, slash and burn method during cultivation or plantation agriculture development, etc. In order to understand how big the burning impact to peat soil parameters change in those three different conditions i.e. before burning (naturally), seven days after burning and ninety days after burning in same site location, accordingly we conducted a study. This research was conducted in Teluk Meranti District, Kampar Peninsular Region, Sumatera, Indonesia. The study was carried out in January till December 2014. The research result showed that same physical and chemical parameters had changed significantly following burning compared to natural condition.***

**Keywords:** Physical, Chemical, Peat soils, Peat fire

## 1. Introduction

Fire has been increasingly recognized as one of the major threats to the remaining peat swamp forests in Indonesia. Due to the inherent characteristics of the peat soil, disturbed peat swamp forests are highly susceptible to fire especially during a prolonged dry season. Like any other wetland, the bio-physical and geochemical processes as well as the functioning of peat swamp forests are very much controlled by its hydrological regimes [23,18].

Peat fires in the wet tropics are of threat to health of millions people and through the emission of carbon to the atmosphere a significant contribution to the greenhouse effect [35,29]. The impact of peat fires through a haze over thousands of kilometers is not a new phenomenon. The problem of haze became widespread in the smoke-haze pollution and un-natural disasters in Indonesia [1] even throughout in Southeast Asia [16, 22]).

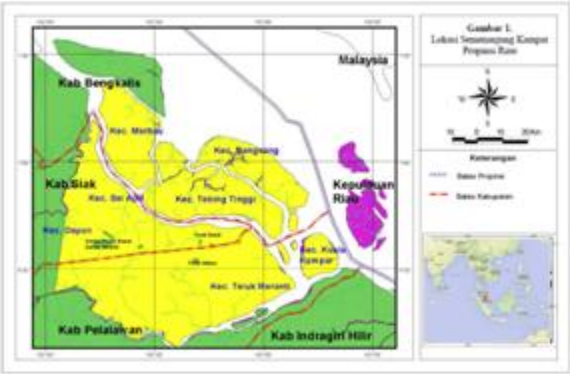
Peat fires have been reported in areas where there had been land clearing or over illegal logging due to human activities[32,10,21]. Peat soil has been reported to burn over large areas in the upper 30 cm. Topsoil. This is because the top layer of drained peat is normally dried and is an extremely good burning material. Once ignited, it spreads easily and the fire is extremely difficult to put out [15].

Most of the fires in peat areas are classified as ground fire. This type of fire occurs in subsurface organic fuels such as duff layers under forest stands, arctic tundra and organic soils of bogs, swamp and peat [8]. Peat fire is dominated by shouldering combustion under the soil surface, penetrating into deeper horizons of the soil, burning out funnel shaped pits and then spreads in a horizontal manner [4]. A study conducted by [2] shows that fire caused considerable changes in the vegetation composition and structure of the burned forest. It also changed the chemical and physical characteristics of the peat soil [19,20].

In addition, the burningwill impact to environment, social, cultural and economic, especially for local community[39,24], otherwise it will change to physics and chemistry peat soilsparameters[12,9,25,3]. The destruction of forests and swamp peat ecosystem will contribute to climate change as a result of the increase in greenhouse gas emissions that are released into the air while burning [15,17].

The experiment was carried out on a farmer's peat swamp forest near the village of TelukMeranti, one of the local districts in Pelalawan Regency, Riau Province, and Sumatera Island, Indonesia (Figure 1). This area that has been accused of forests and peat fires are categorized as the vulnerablearea[30]. Besides that, approximately 92.02 percent of total area with 4,239.44 sq. km as peat swamp forests in the region and it is treated as peat swamp forest hydrologyconservation area in Sumatera, Indonesia[6].

Teluk Meranti located also as part of Semenanjung Kampar Peninsular region that famous asrest of one the key areas of biodiversity peat swamp forest [11] and birdlifearea conservation in Sumatera Island[5].In addition, the main function of this area as stabilizing of micro and macro climate change, carbon sequestration protection and hydrologicalcatchmentarea for fresh water source that released during dry session[6].




## 2. Material and Method

### 2.1. Research Time and Place

The study was carriedout between January 2014 and December 2014 on peatlands in the area belonging to the local government of Teluk Meranti District, Pelalawan Regency, and Riau Province, Indonesia. The site is located between 0°41'30"N–0°03'30"S and 103°12'54"E–102°12'54"W.

Figure 1. Location study in Teluk Meranti District as part of Kampar Peninsular Region in Sumatera Island Indonesia(modified after [30]).

Majority, the climate in area study is almost similar to other area climate conditions in the rest of Riau Province. Generally, the site has a tropical climate with annual rainfall ranging between 1,949 mm/yr and 2,951 mm/yrwithtotal day rain ranging between 151 day/yr and 181 day/yr, 9 month/yr wet and 2-3 month/yr dry. The average daily temperature is 27° C with minimum 22°C and maximum 31°C[7].

Peat bogs occupy hollows sounding Kampar River; can be very deep peat (more than 6.5 m), the flow of water from acidic peat swamp forests and colored black or reddish. The peat soil classification based on field assessment categorized asfibric and hemic decomposition types as shown in Table1.

**Table 1:** Sampling point location, total peat depth, peat color and decomposition level

| Sampling number | Total Peat depth | Peat color | Peat Decomposition |
|---|---|---|---|
| #1 | 8 m | 0-10 cm (10YR 2/1) | Fibric |
| | | 10-50 cm (10YR 2/2) | Hemic |
| #2 | 6.5 m | 0-10 cm (10YR 2/2) | Fibric |
| | | 10-50 cm (10YR 3/2) | Hemic |
| #3 | 7 m | 0-10 cm (10YR 2/1) | Fibric |
| | | 10-50 cm (10YR 3/1) | Hemic |

Based on laboratory analysis shows the peatsoil physical properties on the site study is very acidic, with pH ranging between 3.72 and 4.09 in natural condition. According to previously studied by Saharjo (1999) where peat of the fibric type has a low level of decomposition and a low percentage of humus, which results in very lownutrition protection capacity. Because of the lack of humid materials, fibric peat is a poor medium for agricultural activity. Fibric peat also has a high porosity. Peat of the hemic type has a moderate level of decomposition and consists of several humic materials–hence its better ability in nutrition protection than fibric peat. Hemic peat is a good medium for agricultural activity as long as it still has a high content of humic materials.

### 2.2. Data Sampling

To aim the objective so the research was conducted in the fieldand in the laboratory. Based on the site assessments, three sampling points were observed with labelled as natural condition ($Snc_1$, $Snc_2$, $Snc_3$), seven day following burning ($Ssdb_1$, $Ssdb_2$, $Ssdb_3$), and ninety day following burning ($Sndb_1$, $Sndb_2$, $Sndb_3$) were chosen to represent research sites. Random peat samples were taken in the plot with total depth 0–25cm. The peat soils were collected using copper ring cylinder 10 cm in diameter to allow the samples to retain their natural characteristics in laboratory analysis. Each sampling point was taken by divided into five intervalsi.e. 0-5 cm, 5-10 cm, 10-15 cm and 15-25 cm and then later we had composited to calculate the average value.

### 2.3. Research Material

The properties of peatsoil analyzed for physical and chemical. The physical properties were identified including bulk density, porosity, water content and permeability. The chemical properties includingsoil pH ($H_2O$), available organic-C, ash content, total nitrogen, phosphorus, magnesium, exchangeable cations calcium, natrium, base saturation, and cation exchange capacity. These peatsoil physical and chemical properties were analyzed at the laboratory of Soil Science, Faculty of Agriculture, Riau University, Pekanbaru, Indonesia.

### 2.4. Data Analysis

The physical and chemical peat soils properties were analyzed trough *in-situ* and *ex-situ* analysis. Laboratory analysis was carried out according to [37] methods as shown in Table2.

**Table 2:** Physical and chemical peatsoil parametersmeasured and analytical methods

| Parameters | Methods | Unit |
|---|---|---|
| *Physical parameters* | | |
| Bulk density | Gravimetric | $g/cm^3$ |
| Particle density | Gravimetric | $g/cm^3$ |
| Water content | Gravimetric | % vol. |
| Porosity | Calculation | % |
| Permeability | Lambe | cm/hr |
| *Chemical parameters* | | |
| Soil pH ($H_2O$) | pH Meter | |
| Cation exchange capacity | N $NH_4OA_c$ pH7 | me/100g |
| Natrium | Kjeidahl | % |
| Available phosphorus | *HCL 25%* | *ppm* |
| Potassium | HCL 25% | me/100g |
| Exchangeable cations calcium | N $NH_4OA_c$ pH7 | mg/g |
| Sodium | N $NH_4OA_c$ pH7 | mg/g |
| Magnesium | N $NH_4OA_c$ pH7 | mg/g |
| Base saturation | *Kjeidahl* | % |
| Ash content | Dry ash | % |
| Organic-C | Dry ash | % |

At the first step, we were calculated the average value of individual parameters. Then continue with one-way analysis of variance (ANOVA) test for variables from measurements were used to compare the differencesof those three conditions. To help data calculation and analysis so we had used SPSS$^{TM}$ software version 17.

## 3. Result and Discussions

### 3.1. Result

The summary both of physical and chemical peatsoil characteristic analysis before and after burning were summarized inTable3.

**Effect of fire to physical properties**

Apparently, bulk density and particle density were increased ($p \leq 0.05$) for seven days post-burning compared to that of natural condition. In contrary, porosity decreased significantly. While water content and permeability trend to decreaseeven though statistically was not significant.

Ninety days post-burning compared to that of natural condition where water content was increased significantly. In contrary, bulk density was decreased significantly while particle density and permeability trend to decrease even though statistically was not significant.

Ninety compared to seven days post-burning where porosity and water content were increased significantly ($p<0.05$). In contrary, bulk density decreased significantly then followed by permeability decreased eventhough statistically was not significant while particle density was not changed.

**Effect fire to chemical properties**

Apparently, pH, potassium, exchange cations calcium, sodium and natrium increased significantly followed by cation exchange capacity and ash content increased also but statistically were not significant post-burning compared to that of natural condition. In contrary, natrium decreased significantly while phosphorous, organic-c, magnesium and base saturation decreased but statistically was not significant.

Ninety post-burning compared to that of natural condition where pH increased significantly then followed by organic-c, ash content, phosphorous, cation exchange capacity increased also but statistically not significant. The exchange cation calcium decreased significantly while potassium, magnesium and base saturation decreased also but statistically was not significant while the natriumwas not changed.

Ninety days post-burning compared to that of seven days post-burning where ash content, natrium, available phosphorous and cation exchange capacity increased but statistically was not significant. In contrary, the exchangeable cation calcium and sodium decreased significantly then followed by organic-c, potassium and base saturation but statistically was not significant while the pH was not changed.

### 3.2.Discussion

Peat destruction by fire affects the soil physical and chemical properties. The effect of fire on the chemical and physical properties of peat soil varies significantly depending on the type of soil, its moisture content, the intensity and duration of the fire, and the timing and intensity of post fire precipitation [9]. Soil properties may also change in response to heat and increased exposure [28].

**Tabel 3:** Mean values, standard deviations and mean comparation test of nutrient mass fraction measured of the physical and chemical peatsoil parameters before and after burning

| Parameters | Before burning (Natural conditions) | After burning | |
|---|---|---|---|
| | | Seven days | Ninety days |
| *Physical properties* | | | |
| Bulk density (g/cc) | 0.17±0.15 | 0.20±0.02[a] | 0.16±0.01[c] |
| Particle density (g/cc) | 1.06±0.01 | 1.09±0.02[a] | 1.06±0.01[c] |
| Porosity (%) | 83.74±1.18 | 81.39±1.87[a] | 84.31±1.28[b,c] |
| Water holding capacity (%) | 223.90±70.00 | 144.93±79.70 | 929.07±120.61[b,c] |
| Permeability (cm/hr) | 40.08±23.06 | 35.61±12.75 | 29.62±19.41 |
| *Chemical properties* | | | |
| pH | 3.88±0.11 | 4.16±0.28[a] | 4.16±0.29[b] |
| Organic-c (%) | 45.58±2.64 | 45.68±3.99 | 44.71±5.30 |
| Ash content (%) | 8.82±5.29 | 8.61±7.99 | 10.57±10.60 |
| Natrium (%) | 0.69±0.23 | 0.52±0.12[a] | 0.69±0.08 |
| Phosphorous (ppm) | 15.41±9.31 | 39.29±43.22 | 39.51±41.16 |
| Potassium (me/100g) | 0.15±0.06 | 0.47±0.41[a] | 0.02±0.01[c] |
| Exchangeable cation calsium (me/100g) | 0.36±0.15 | 0.56±0.20[a] | 0.07±0.02[b,c] |
| Sodium (me/100g) | 0.02±0.01 | 0.05±0.00[a] | 0.02±0.00[c] |
| Magnesium (me/100g) | 0.11±0.00 | 0.10±0.03 | 0.08±0.05 |
| Cation exchange capacity (me/100g) | 81.78±7.22 | 81.82±7.62 | 83.34±7.04 |
| Base saturation (%) | 7.75±24.01 | 1.47±0.52 | 0.22±0.01 |

*Significant at $p \leq 0.05$ with legend (a) seven days post-burning compare to that of natural condition, (b) ninety days post-burning compared to that of natural condition, and (c) ninety days post-burning compared to that of seven days post-burning.*

Changes in soil chemical properties will also affect the soil physical properties because the mean effect of heating was destruction of the structure in the surface layer. The soil of the burnt area is no longer protected from the beating action of raindrops and it becomes dispersed and compact so that finally soil permeability will decrease [13], as was found in all burnt sites in this study. Besides destroying the litter layer, heat also destroyed insects and other micro-organisms that channel the soil, resulting in reduction of soil porosity [32], as was found also in the sites burnt for this study.

The decrease of calcium, magnesium, potassium, and sodium following burning may have been caused by leaching and runoff as a result of vegetation destruction [36,34], while the increase in nutrients resulted from the presence of ash [14,32]. Losses of nutrients following burning are likely the result of leaching and surface runoff caused by rain several weeks after burning. Losses of organic matter and nutrients can continue long after a fire event through erosion, leaching, and volatilization. The presence or absence of duff, humus, and other unincorporated organic materials on the forest floor and the amounts consumed are of key importance in determining how the soil is affected [8], and [31] has shown that even if there were changes in soil chemical properties following burning in the cultivation area, they did not improve soil fertility.

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These facts show that using fire for land preparation, especially in peat areas, i.e. shifting cultivators or agriculture development recently by companies, will eventually degrade the peatsoil parameters then later will finally minimize peatsoil sustainability. Furthermore the impact of burning of peat depends on the level of peat decomposition. Burnt peat, as mentioned above, will never return to the original state because peat depth decreases every time a fire is used for land preparation[32].

The situation becomes dangerous when biomass (as fuel) use is not selective and no special treatment is used during burning. As long as fire is used, whether by shifting cultivators or, recently, by companies, the future of peat is uncertain. It is predicted that if fire is continued to be used in peat areas without any treatment to prevent peat destruction, then in a few short years peat will be totally lost, as has occurred in South Sumatra where 3 m deep peat has vanished in 20 years' time[33,26,27].

However, as land attributes are complicated in their composition and distribution, predicting the impact of spatial variability on the behavior or response of systems to most management strategies has been challenging. There is a mismatch between the wealth of knowledge available on peatlands and the sustainability of management options utilized to conserve these non-renewable resources.

Peatlands display tremendous spatial variability in critical physical and chemical properties. These properties have a major role in determining the quality of such systems. The subject matter is even more complicated when these properties are evaluated in terms of their inherent resilience to anthropogenically-induced changes. Designing risk -management strategies or even attempting to rehabilitate such systems requires examining these properties from the resilience stand point.

Diminished output of response curves to resilience-based systems is apparent. The loss in terms of profitability cannot be argued. However, with the impact of spatial variability taken for granted, the gain in terms of preserving the original properties and maintaining the land quality in a truly sustainable manner is evident. It is therefore imperative that management strategies consider the impact of spatial variability to maintain stewardship over these non-renewable natural resources.

Peat areas are sensitive ecosystem. Peat catches fire easily if it is dried because of its organic nature. In its natural condition peat is not expected to catch fire as the water table reaches the ground surface and/or the peat deposit is completely saturated. Peat forests in an undrained peat basin are not expected to catch fire. Therefore to prevent the onset of fire in peat forests the peat basin should be managed in a manner that will minimize the drainage of the land and keep the deposit continuously wet and at a high water table level.

The data reported in this paper indicate that regular use of fire for land preparation in peatland, without any treatment to prevent peat destruction, will decrease the quality of peat and finally result in the total disappearance of peat forever.

Although burning increases the amount of nutrients in the soil, which temporarily enhances growth performance, it also has negative effects. As has been reported for several parts of Indonesia, peatlands being burned repeatedly for land preparation will significantly reduce in depth. This negative consequence is especially important for cultivators that depend on cultivation on peatlands for a large part of their income. This paper provides facts on the relation between regular peat burning for land preparation and the status of burnt peatlands in the near future, especially in human activity - land use and land cover change that caused to peat fire.

## 4. Conclusion

The slash and burn method during cultivation or plantation agriculture development etc. will impact an increase or decrease of some of physics properties seven days following burning, but it will decline again ninety days or later. Following burning also has been tremendousincrease the chemical properties in seven days, but decrease again in ninety days or after.

There is an urgent need for a more concerted action in TelukMeranti District to minimize or stop the continuous loss and degradation of peatlands, as a result of increasing unsustainable exploitation or development activities which are leading to degradation and increased susceptibility to forest fires.

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## References

[1] Aiken, S.R. 2004. Runaway Fires, Smoke-Haze Pollution, and Un-natural Disasters in Indonesia. The Geographical Review 94 (I): 55-79.
[2] Ainuddin, N.A. , Kelvin, G. and Jamaluddin, B., 2001. Effect of forest fire on vegetation in Raja Musa Forest Reserve.Abstract in Symposium Programme and Asbtracts Asian Wetland Symposium. 27-30 August, 2001. Penang.pp. 36.
[3] Andriesse, J. P. 1988. Nature and Management of Tropical Peat Soils. Food and Agricultur Organization of The United Nation. Rome.
[4] Artsybashev, E.S. 1983. Forest Fires and Their Control.Oxonian Press. New Delhi, India. 160 pp.
[5] Birdlife International. 2003. Important Bird Areas in Asia: Key Sites for Conservation. Cambridge, UK: Birdlife International (Birdlife Conservation Series No. 13).
[6] BLH (BadanLingkunganHidup) Provinsi Riau. 2010. StrategiPengelolaanEkosistemRawaGambut. UntukPenurunanEmisi Gas RumahKaca (GRK) dalamRangkaAdaptasidanMitigasiPerubahanIklim.Seminar danLokakaryaRevitalisasidanPenguatanJejaringKerjasamaPusatPenelitianLingkunganHidupLembagaPenelitian Universitas Riau, Pekanbaru.
[7] BMKG (BadanMeteorologiKlimatologidanGeofisika) Pekanbaru. 2014. LaporanKlimatologi. Pekanbaru.
[8] Brown, A.A. and Davis, K.P. 1973. Forest Fire Control and Use. McGraw Hill Inc. New York. 686 pp.
[9] Chandler C, Cheney P, Thomas P, TrabaudL,Williams D (1983) Fire in Forestry, Vol. 1: Forest Fire Behavior and Effects. John Wiley and Sons, New York, pp 450
[10] Christian P. Giardina, Robert L. Sanford Jr., Ingrid C. Døckersmith& Victor J. Jaramillo.1999. The effects of slash burning on ecosystem nutrients during the land preparation phase of shifting cultivation. Kluwer Academic Publishers. Plant and Soil 220: 247–260.
[11] CIIP (Conservation International Indonesia Programme). 2007. Priority Sites for Conservation in Sumatra: Key Biodiversity Area.
[12] de Bano, L.F., D.G. Neary, and P.F. Flolliot. 1998. Fire’s Effect on Ecosystems. John Willey and Sons, Inc. New York.
[13] Fuller, M. 1991. Forest Fire.An Introduction to Wild Land Fire Behaviour, Management, Fire Fighting and Preventif. John Wiley and Son’s Inch, New York. P:69-77.
[14] Griffith AL (1943) The Effect of Burning on the soil as Preliminary to Artificial Regeneration. Indian Forestry Bulletin Forest Research Institute Dehra, pp 130.
[15] Hooijer, A., Silvius, M., Wösten, H. and Page, S. 2006. Peat-$CO_2$, Assessment of $CO_2$ Emissions from Drained Peatlands in SE Asia. Delft Hydraulics report Q3943 (2006).
[16] Jones, D.S. 2006. ASEAN and Transboundry Haze Pollutant in Southeast Asia. Asia Europe Jurnal Volume 4, Issue 3, pp 431-446.
[17] Joosten, H. 2009. Peatland Status and Drainage Related Emissions in All Countries of The World. The Global Peatland CO2 Picture.Wetlands International.
[18] KLH (KementerianLingkunganHidup) Republik Indonesia. 2010. ProfilEkosistemGambut di Indonesia.
[19] Lailan, S and Ainuddin, N A. 2000. The effects of forest fire on peat soil properties: A case study in Sungai Karang Forest Reserve, Selangor. In Proceedings SOILS 2000: Soil Science Conference of Malaysia. pp. 74-78.
[20] Lailan, S, Ainuddin, N.A. and Jamaluddin ,B. 2001. Fire effects on physical and chemical peat properties in Sungai Karang Forest Reserve, Selangor. . Abstract in Symposium Programme and Asbtracts Asian Wetland Symposium. 27-30 August, 2001. Penang.pp. 229.
[21] Lavorel, S., Flannigan, M,D., Lambin, E.F., Scholes, M.C. 2007. Vulnerability of Land Systems to Fire: Interactions Among Humans, Climate, The Atmosphere, and Ecosystems. Mitig Adapt Strat Glob Change (2007) 12:33–53.
[22] Litta, H. 2012. Case Study One: Transboundary Haze Pollutant. Regimes in South Asia.pp89-138.
[23] Mitsch, W.J. and J.M. Gosselink. 2000. Wetlands. Third Edition.John Wiley & Sons, Inc.
[24] Murdiyarso, D, danAdiningsih, E. S. 2007. Climate Anomalies, Indonesian Vegetation Fires and Terrestrial Carbon Emissions.Mitig Adapt Strat Glob Change (2007) 12:101–112.
[25] Nishita, H.R.M. Haug., M. Hamilton and G.V. Alexander. 1970. Influence of Soil Heating on the Growth and Elemental Composition of Bean Plant. Soil Sci.
[26] Parish, F. and Jamil H.(eds.) 2000. Management inventory of North Selangor Peat Swamp Forest.Danced-Forest department Kuala Lumpur.
[27] Parish, F. 2002. Overview on peat, biodiversity, climate change and fire.Proceedings of workshop on prevention and control of fire in peatlands. Forestry Training Unit, Kepong Kuala Lumpur. 19th-21st March 2002.
[28] Ralston CW, Hatchell GE (1971) Effects of prescribed burning on physical properties of soil. in Prescribed Burning Symposium USDA For. Serv Southeastern For ExpSta, pp 68–84.
[29] Rieley, J.O., Ahmad-Shah, A. A. and Brady, M.A. 1996. The extent and nature of tropical peat swamps. In: Tropical Lowland Peatlands of Southeast Asia. Eds.: E. Maltby, C.P. Immirzi and R.J. Safford. July 1992. IUCN, Gland, Switzerland, pp. 17-53.
[30] Rifardi. 2008. DegradasiEkologiSumberdayaHutandanLahan (StudiKasusHutanRawaGambutSemenanjung Kampar Propinsi

Riau).FakultasPerikanandanIlmuKelautanUniversitas Riau.JurnalBumi Lestari, Vol. 8 No. 2, Agustus 2008.

[31] Saharjo, B. H. 1995. The changes in soil chemical properties following burning in a shifting cultivation area in South Sumatra.Wallaceana 75:23–26.

[32] Saharjo, B. H. 1999. The effects of fire on the properties of soil in Acacia mangium plantations in South Sumatra, Indonesia. Journal of Tropical Forest Science 11(2):459–469.

[33] Saharjo, B. H. 2007. Shifting Cultivation in Peatlands.Mitig Adapt Strat Glob Change (2007) 12:135–146.

[34] Saharjo, B. H and Makhrawie. 1998. The changes in soil chemical properties after fire in four-year-old Acacia mangium and Eucalyptus urophylla plantations. Tropical Ecology 39(1):97–102.

[35] Siegert, F., G. Ruecker, A. Hinrichs& A.A. Hoffmann. 2001. Increased damage from fires in logged forests during droughts caused by El Nino. Nature vol 414437-440.

[36] Toky, O. P and Ramakhrisnan, P. 1981. Run-off and infiltration losses related to shifting agriculture (jhum) in northeastern India. Environmental Conservation 8:313–321.

[37] USDA. 1975. A Basic System of Soil Classification for Making and Interpreting Soil Survey. S.C.S. USDA Handbook No. 436, Washinton D.C.

[38] Wahyunto, dan A. Mulyani. 2011. PengelolaanLahanGambutBerkelanjutan. Balai Besar LitbangSumberdayaLahanPertanian. BadanPenelitiandanPengembanganPertanianKementerianPertanian. Bogor.

[39] Whelan, R.J. 1995. The Ecology of Fire.Cambridge University Press. New York. 343 p.

## Author Profile

**Budi Darmawan** is a student Doctoral program of Department Environment Science, Riau University, Indonesia.

**YusniIkhwan Siregar** is a Professor of Environmental Science and Ecotoxilogy Departmentin Riau University, Indonesia.

**Sukendi** is a Professor of Environmental Science and Fish Biology Reproduction department in Riau University, Indonesia.

**Siti Zahra** is a Doctoralof Environmental and Soil Science in Agriculture department, Islamic University of Riau, Indonesia.