

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 differences of those three conditions. To help data calculation and analysis so we had used SPSS™ software version 17.

3. Result and Discussions

3.1. Result

The summary both of physical and chemical peat soil characteristic analysis before and after burning were summarized in Table 3.

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 decrease even 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 even though 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 natrium was 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].

Table 3: Mean values, standard deviations and mean comparison test of nutrient mass fraction measured of the physical and chemical peat soil parameters before and after burning

Parameters	Before burning (Natural conditions)	After burning	
		Seven days	Ninety days
<i>Physical properties</i>			
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
<i>Chemical properties</i>			
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 calcium (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 tremendous increase 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 (1): 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 Abstracts Asian Wetland Symposium. 27-30 August, 2001. Penang. pp. 36.
- [3] Andriessse, J. P. 1988. Nature and Management of Tropical Peat Soils. Food and Agriculture 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 (Badan Lingkungan Hidup) Provinsi Riau. 2010. Strategi Pengelolaan Ekosistem Rawa Gambut. Untuk Penurunan Emisi Gas Rumah Kaca (GRK) dalam Rangka Adaptasi dan Mitigasi Perubahan Iklim. Seminar dan Lokakarya Revitalisasi dan Penguatan Jejaring Kerjasama Pusat Penelitian Lingkungan Hidup Lembaga Penelitian Universitas Riau, Pekanbaru.
- [7] BMKG (Badan Meteorologi, Klimatologi dan Geofisika) Pekanbaru. 2014. Laporan Klimatologi. 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, Trabaud L, 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-CO₂, Assessment of CO₂ 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 (Kementerian Lingkungan Hidup) Republik Indonesia. 2010. Profil Ekosistem Gambut 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 Abstracts 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. pp 89-138.
- [23] Mitsch, W.J. and J.M. Gosselink. 2000. *Wetlands*. Third Edition. John Wiley & Sons, Inc.
- [24] Murdiyarsa, D, dan Adiningsih, 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. Degradasi Ekologi Sumberdaya Hutandan Lahan (Studi Kasus Hutan Rawa Gambut Semenanjung 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 414:437–440.
- [36] Toky, O. P and Ramakhrisan, 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. BadanPenelitiandanPengembanganPertanianKementeria nPertanian. 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 Ecotoxology 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.