Abstract No: A-181

CHANGE OF WATER CHEMISTRY (DISSOLVED ORGANIC CARBON) WITH FREQUENT PEAT FIRES IN INDONESIAN PEATLAND

Masayuki Itoh[1*], Hiroshi Nishimura[1], Satomi Shiodera[1], Takashi Hirano[2], Osamu Kozan[1] and Haris Gunawan[3]

[1]*Kyoto University, Japan*
[2]*Hokkaido University, Japan*
[3]*Riau University, Indonesia*

**Corresponding author: masayukiitoh@yahoo.co.jp*

SUMMARY

Tropical peat swamp forests in Southeast Asia had been considered to be one of the most important parts of larger ecosystems due to the huge amount of carbon stock. Yet, recent rapid and intensive deforestation to procure timber and land preparation for commercial plants or crops (oil palm or Acacia plantations) have induced fundamental changes in the material cycling. Especially, frequent peat fires occur in every dry period especially in Indonesia, which changes the environment fundamentally and emit huge amount of greenhouse gases. We focused on the effects of human impacts on groundwater chemistry in the degraded peatland area in East part of Sumatra Island and Central Kalimantan, Indonesia by comparing with the observation in intact peat swamp forest and secondary forest with no fire experiences. We analyzed both the quantity and quality of dissolved organic and inorganic matters in peatland groundwater and canal water. Our results suggest that frequent peat fires had great effect on change in water chemistry in both quality and quantity aspects especially of dissolved organic carbon.

Keywords*: tropical peatland, groundwater, dissolved organic carbon, peat fires, drainage*

INTRODUCTION

Tropical peat swamp forest is a tropical moist forest where waterlogged condition prevents the decomposition of dead woods and leaves. In Southeast Asia, peat swamp forest is one of the typical landscapes that regulate material cycling. According to a recent report, tropical peatland area encompasses 441,025 km^2 in which account for approximately 11% of global peatland area and in Southeast Asia alone, consist of 247,778km^2 or 56% of the total area of tropical peatland (Page *et al.*, 2011). These forests are known to be ecological dominance of terrestrial and aquatic biodiversity (Yule, 2010). Nevertheless, a recent statistic showed that these highly disturbance-sensitive forests were massively explored, declining 5.1 Mha or 42% of the total current intact peat swamp forests compared to those in last two decades (Miettinen and Liew 2010).

Under social and economic pressure, recent rapid and intensive deforestation to procure timber and convert land for more commercial plants or crops (oil palm or rubber plantations) (Koh *et al.*, 2009) have caused fundamental changes in land use pattern and material cycling. Carbon sequestration rates in tropical peatlands exceed 80 g C m^2 yr^{-1} (Page *et al.,* 2004) and is now decreasing due to intensive drainage following land conversion. The extensive anthropogenic activity in the form of deforestation for valuable logs and land conversion to agro-industrial plantations expedites peat fire following ground water drainage (Figure 1). The prolonged periods of annual drought and flood further result in the instability of soil condition physically and chemically.

Lowering of water table by constructing drainage canals allows the surface of peat to turn into aerobic condition. This increases decomposition rates. Aerobic respiration by microbe increases oxygen concentration in peat. This induces the increase in larger amount of carbon emission as CO_2 (e.g. Freeman *et al.*, 1992) and dissolved organic carbon (DOC). As a result, peat can be easily oxidized, releasing a large amount of DOC (Freeman *et al.*, 2001; Clair *et al.*, 2002). Recently, in Central Kalimantan, Indonesia, Moore *et al.* (2013) showed that fluvial DOC discharge from disturbed peat swamp forest was 50% larger than that from an intact forest. They also showed that the carbon which was discharged from disturbed forest contained old carbon. This indicates the impact by human activity on the material cycling in peat swamp forests.

In addition, over several millennia, fire has been of common feature in the tropical peatland. However, within the past three decades, catastrophic fires seem to occur more frequently than ever, particularly during extended periods of drought in association with El Niño events (Yulianti *et al.,* 2012) and also being tightly linked to the change of land-used types in these recent years, such as oil palm plantation conversion when slash and burn techniques is always the option as the cheapest mean of land clearing (Langner and Siegert 2009). Under such

situation, this paper discusses the impact of land use changes and repeated fire effect on water chemistry (especially carbon concentration) in Indonesian tropical peatland.

METHODS

Site description and hydrological features

The study was conducted in the East part of Sumatra Island and Central Kalimantan in Indonesia. At the site in Sumatra, repeated fire in peat swamp forest changed the environment from swamp forest to degraded bare land. A degraded peatland field was selected (hereafter: DP; Photo 1a) which experienced fire three times in 2002, 2004, and 2007, located in Riau province. An unburnt but drained secondary forest situated in the next village was also made (hereafter UBD). The number of water sample collected depended on the groundwater level at each sampling time and location. Groundwater from wells in undrained peat swamp forest was collected (hereafter: UF), drained peat forest (DF), and drained burnt area (DB) in Central Kalimantan. Water table levels were taken manually using a water-level indicator and continuously monitored by water level sensor. Precipitation was also measured in both sites.

Water collection and analysis

Water samples were collected from canals and piezometers; 1 m depth to measure water chemistry. *In situ* measurements of pH and electrical conductivity (EC) were carried out. To measure dissolved organic carbon (DOC) concentrations and total dissolved nitrogen (TDN), the water samples were first filtered using glass-fiber filters (GF/F; nominal particle retention, 0.7 μm; Whatman, UK). Then, DOC and TDN concentrations were determined using a total organic carbon (TOC) analyzer (TOC-V; Shimadzu, Japan). To examine the quality difference in dissolved organic matter (DOM), the excitation emission matrix (EEM)s were acquired on Aqualog (Horiba Scientific) with the following settings: Ex = 240 to 600 nm at every 3-nm interval, Em = 212 to 619 nm at every 3 nm interval, bandpass = 5 nm and integration time = 0.1 s. EEMs were corrected for any instrument bias, and inner filter corrections were applied using the absorbance values. Blank subtraction of ultrapure water was carried out to remove Raman scattering effects and a solvent effect.

RESULTS AND DISCUSSION

Here, the results of Riau site are presented. Seasonal variations in daily rainfall (DP site), water table levels, and DOC concentrations at DP and UBD sites are shown in Figure2. The study site has rainy and dry season that is affected by the inter-tropical convergence zonal phenomenon, in which the area experiences a rainy season and two dry seasons throughout a year. During the experimental period, high amounts of precipitation were recorded from November to December 2013 and low amounts from January to May 2014.

Groundwater level in DP site decreased below 120 cm in February 2014 when no rainfall was recorded for two months. In contrast, the groundwater level increased up to soil surface in December 2014 (data not shown). This indicated that the groundwater level fluctuated more than 120 cm at this site. DP site is located adjacent to a canal flowing from the Acacia plantation area. Therefore, in addition to the effect of natural increase of water table level, water management of the plantation might affect the groundwater level at the site. The mean values of DOC concentration in groundwater ranged from 43.5-74.3 (mean 60.6) mg C/L in DP site and from 49.4-94.5 (mean 76.0) mg C/L in UBD site, respectively. There were no significant differences (P=0.15) for DOC concentrations between these two sites. The highest DOC concentration at DP site was observed during the driest period of February 2014.

Although there were no significant differences in DOC concentration between DP and UBD sites, the quality of the DOC was different. Figure 3 shows the three dimensional fluorescence spectra of water collected from burnt drained peat (DP; left) and unburnt drained secondary forest (UBD; right) sites. In both sites, peak was identified at excitation/emission wavelengths (Ex/Em) of 350/430–450 nm, while another peak was identified at Ex/Em of 300/330 nm in only DP site. This difference between sites suggested that the change in DOM quality before and after peat fires, or deforestation (Itoh *et al.* unpublished). Nevertheless, the current data is insufficient to prove the notion, more samplings are now underway. The presentation will include the results from Central Kalimantan site.

CONCLUSION

Preliminary observation in Riau Province, Sumatra, Indonesia, suggested that the impacts of human activities such as forest clear-cutting and peat burning have changed the ecological condition in tropical peatland area in these few decades. Such changes in groundwater quality may be irreversible to original state or may take decades to restore to nearly natural condition. This study also urges the need to have more studies to access the ecological and economic impact in degraded peatlands.

ACKNOWLEDGEMENTS

We thank Mr. Ahmad Muhammad; Mr. and Mrs. Nur for supporting our research. This work was supported by the Ministry of Education, Culture, Sports, Science, and Technology for Science Research (15H05625), Global Environment Research Fund (4-1504), Ministry of Environment, Japan, and the Institutional Collaboration Feasibility Studies, Research Institute for Humanity and Nature (RIHN), Japan.

REFERENCES

1. Clair, T.A. *et al.* (2002) Gaseous carbon dioxide and methane, as well as dissolved organic carbon losses from a small temperate wetland under a changing climate, Environmental Pollution 116, S1, S143–S148.
2. Freeman, C. *et al.* (1992) Fluxes of CO_2, CH_4 and N_2O from a Welsh peatland following simulation of water table draw-down: potential feedback to climatic change
3. Freeman, C. *et al.* (2001) Export of organic carbon from peat soils, Nature, 412, 785
4. Koh, P.K. *et al.* (2009) Conversion of Indonesia‘s peatlands. Frontiers in Ecology and the Environment 7 (5), 238–238.
5. Langner, A., and Siegert, F. (2009) Spatiotemporal fire occurrence in Borneo over a period of 10 years. Global Change Biology 15: 48-62.
6. Miettinen, J., and Liew, S. C (2010) Degradation and development of peatlands in Peninsular Malaysia and in the islands of Sumatra and Borneo since 1990. Land Degradation & Development 21: 285-296.
7. Moore, S. *et al.* (2013) Deep instability of deforested tropical peatlands revealed by fluvial organic carbon fluxes, Nature, 493, 660–664
8. Page, S. E. *et al.* (2004) A record of late Pleistocene and Holocene carbon accumulation and climate change from an equatorial peat bog (Kalimantan, Indonesia): implications for past, present and future carbon dynamics. J. Quat. Sci. 19, 625–635
9. Page, S. E. *et al.* (2011), Global and regional importance of the tropical peatland carbon pool. Global Change Biology 17: 798–818.
10. Yule, C. M. (2010) Loss of biodiversity and ecosystem functioning in Indo-Malayan peat swamp forests. Biodiversity and Conservation 19: 393-409.
11. Yulianti, N., *et al.* (2012) Recent forest and peat fire trends in Indonesia: The latest decade by MODIS hotspot data. Global Environmental Research 16: 105-116.

Figure 1: Anthropogenic activities in the form of deforestation and land-used conversion cause ground water drainage in peatland. Intensive drought and raining season could result in wildfires (left) and flood (right).

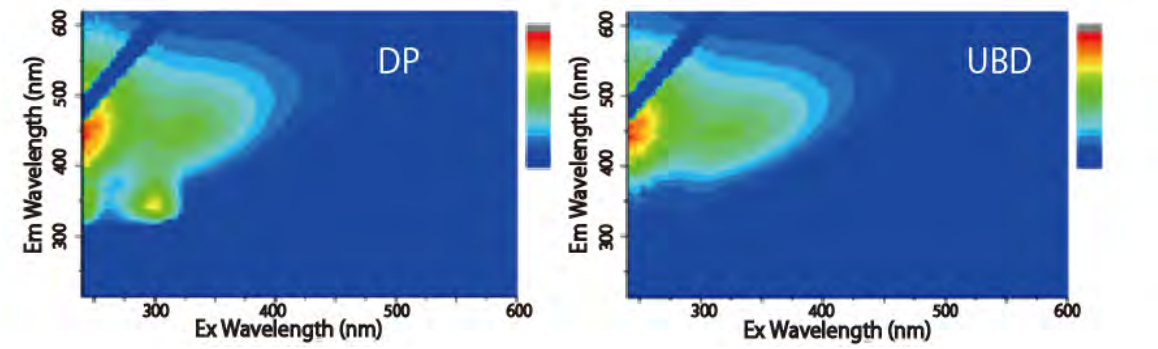

Figure 2: Three dimensional fluorescence spectra of water collected from burnet drained peat (DP; left) and unburnt drained secondary forest (UBD; right) sites. Ex and Em indicate both excitation and emission, respectively (Itoh unpublished).