Abstract No: A-156

ANTHROPOGENIC DISTURBANCES AND RESILIENCE: A MESSAGE FROM THE PAST

Kartika Anggi Hapsari[1*], Siria Biagioni[1], Tim Jennerjahn[2], Peter Reimer[3], Asmadi Saad[4], Supiandi Sabiham[5] and Hermann Behling[1]

[1] *Department of Palynology and Climate Dynamics, Albrecht-von-Haller Institute for Plant Sciences, Georg-August-University of Goettingen, Germany*
[2] *Department of Biogeochemistry and Geology, Leibniz Center for Tropical Marine Ecology (ZMT) Bremen, German*
[3] *Department of Biological Science, Goshen College, Indiana, USA*
[4] *Department of Soil Science, University of Jambi, Indonesia*
[5] *Department of Soil Science and Land Resource, Bogor Agriculture University (IPB), Indonesia*

[*] *Corresponding author: kartika.hapsari@biologie.uni-goettingen.de*

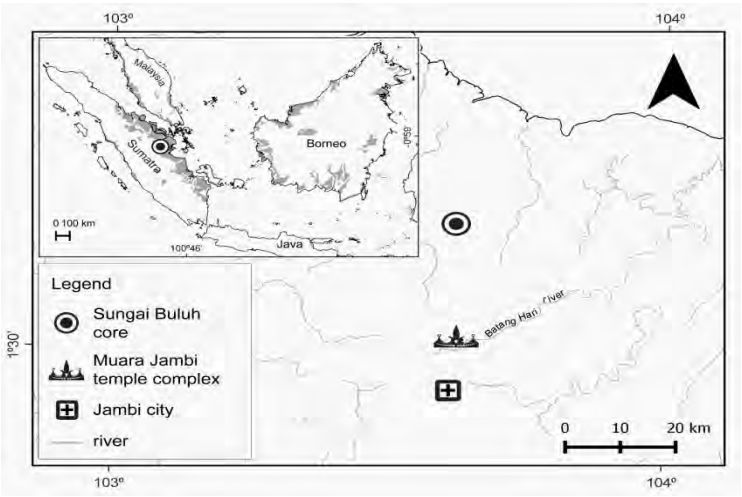
SUMMARY

Despite of the number of studies that have been conducted, knowledge of past human activities on peatlands in Southeast (SE) Asia remains fragmented. Hence, anthropogenic activities on peatlands are considered to be recent. In order to see whether and how human conducted activities on peatland in the past, a palaeoecological study on peatland located close to archaeological site of Malayu Empire was undertaken. The results revealed that human activities on tropical peatland began over a millennium ago. By conducting logging, grazing and wild harvesting activities, human changed the vegetation composition and diminished the ecosystem ability to accumulate peat and carbon. Shortly after the abandonment of the site, the vegetation regenerated and the accumulation rate of carbon recovered.

Keywords: *peatland, long-term data, disturbance, human impact, resilience*

INTRODUCTION

Pressures on peatland in SE Asia due to land use and conversion escalate in the past few decades, following the increase in population demand for food, settlements and resources. In order to prevent loss and to maintain the important functions of this ecosystem, management strategies are urgently required. To create effective management strategies on peatland, it is important to include a historical perspective that can provide valuable knowledge on ecosystem response to disturbance and their resilience (Birks, 2012).
Unfortunately, knowledge on past disturbance of peatland in SE Asia remains a large gap, particularly of human disturbance. The evidences of human activities on peatland are only reported by very limited number of studies (Anshari *et al*., 2001, Yulianto *et al*., 2005, Cole et *al*., 2015). The lack of evidence as well as the requirement for tools and technology to utilize peatland compel the extensive human disturbance is considered to be novel (Cole *et al*., 2015). Therefore, the information how past human interventions controlling vegetation composition and C accumulation in peatlands remains scarce and the understanding the peatland resilience to human-induced disturbance prevail to be missing.
The information of past environment condition is often kept in the natural archive. Peatland is one the natural archives that preserves the palaeo-proxies such as pollen, spores and charcoal. Using palaeoecology, the information from the past therefore can be translated and understood. In order to see whether human



Map of the study site

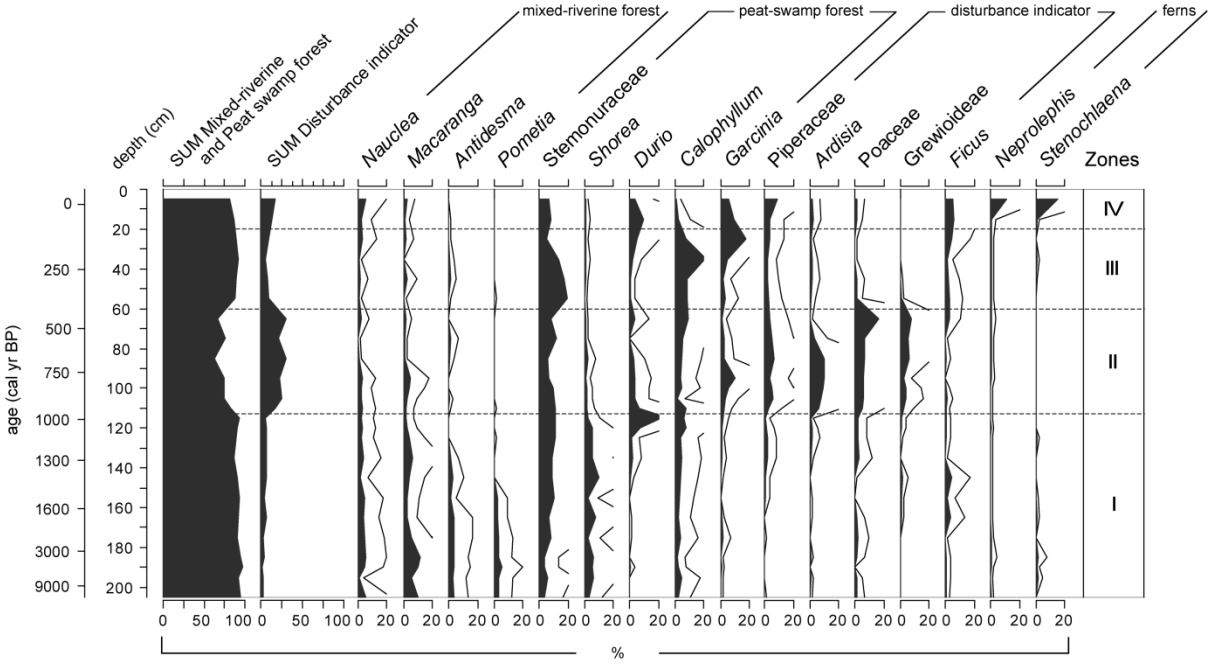
conducted activities on peatland in the past, the natural archive form Sungai Buluh peatland is chosen, as it is located close to Muara Jambi temple complex, the archeological remains of Malayu Empire.
Malayu Empire is one of the largest Empire in Indonesian history located in Jambi, Central Sumatra. The establishment of the Empire is reported as earlier than the 7th century, however the Muara Jambi temple was built later in the 9th century. The Empire demised in the 14th century by the conquest from Javanese kingdom, Majapahit (Witrianto, 2014). Based on the archaeological study, the Muara Jambi temple complex was the capital of the Empire (Witrianto, 2014).
This study was undertaken in order to see (i) whether or not the inhabitant of Malayu Empire conducted any activities on the peatland. If so, (ii) what kind of activities they conducted, (iii) how the activities affected the peatland, and (iv) how the peatland responded.

METHODS

In 2013, a 3.5 m SB-B core was taken from the area of Sungai Buluh peatland and spanning about 23000 years (Hapsari *et al*., submitted). In order to see the condition of Sungai Buluh peatland on pre-, during and post- Malayu Empire times, this study was conducted using the same core and focused on around the depth covering the existence period of the Empire in Muara Jambi (1100 to 500 years ago; 120-60 cm). In order to assess the changes in past vegetation of Sungai Buluh peatland, 25 sub-samples from the first 2 m of SB-B core covering from 9000 cal yr BP to present were analyzed for pollen and spore using the standard method from Faegri and Iversen (1989). The pollen and spores are counted, identified to the finest taxonomical possible using the reference collection of Department of Palynology and Climate Dynamics and other available literatures e.g. (Anderson and Muller, 1975; Jones and Pearce, 2015). The identified taxa are subsequently grouped according to the function and common ecology of the source plants e.g. (Sosef *et al*., 1998; Cole *et al.,* 2015). The results are subsequently combined in the age-depth model of SB-B core constrained from five AMS radiocarbon dates and compared to the peat accumulation rate, carbon accumulation rate and past fire regime that are performed by Hapsari *et al*. (submitted).

RESULTS

The pollen data is presented in pollen diagram prepared using C2 program (Juggins, 2007). The pollen diagram displays the selected pollen and spore taxa and is divided into four zones based on visual inspection. In zone SB I (200-113 cm; 9000-1000 cal yr BP), the pollen is dominated by peat swamp and mixed-riverine forest taxa, while taxa indicating disturbances are presented in low values (average >5%). Zone SB II (113-60 cm; 1000-400 cal yr BP) is characterized by the decrease of the total average value of peat swamp and mixed-riverine forest taxa from 92 to 73%, accompanied by the increase of disturbance indicator taxa from 5 to 24%. In this zone, Piperaceae, Poaceae, Ardisia and Grewioideae increase significantly. Pollen percentage of Poaceae and Grewioideae reach their highest value in the end of this zone. In zone SB III (60-20 cm; 400-100 cal yr BP), the average value of disturbance indicator taxa decrease to 8% followed by the increase of peat swamp and mixed-riverine forest taxa (average 90%). The last zone, SB IV (20-0 cm; 100 cal yr BP to present), is indicated by the increase of disturbance indicator taxa, Piperaceae and *Ficus*, with the average value of 15%. The total average of peat swamp and mixed riverine forest taxa also decrease into 84% in this zone.



Pollen diagram of Sungai Buluh core

From the depth of 200 to 160 cm (9000 to 1600 cal yr BP), the average value of C accumulation is low (9 g C/m^2 yr). It increases to 91 g C/m^2 yr between the depth of 160 and 145 cm (1600-1300 cal yr BP) and subsequently decreases between the depth of 140 and 70 cm (1300-500 cal yr BP; 65 g C/m^2 yr). The C accumulation rate re-increases in the depth of 70 to the top of the core (500 cal yr BP-modern) with the average value of 102 g C/m^2 yr.

In 9000 to 3000 cal yr BP, the charcoal analysis suggests the period of low fire frequency in the record with average 1 fire episode/1000 year. The fire frequency then increases between 3000 and 1200 cal yr BP with average 4 fire episodes/1000 year. From 1200 to 500 cal yr BP, the fire frequency decreases to average 2 fire episodes/1000 year and subsequently increases to average 3 fire episodes/1000 year from 500 cal yr BP to present.

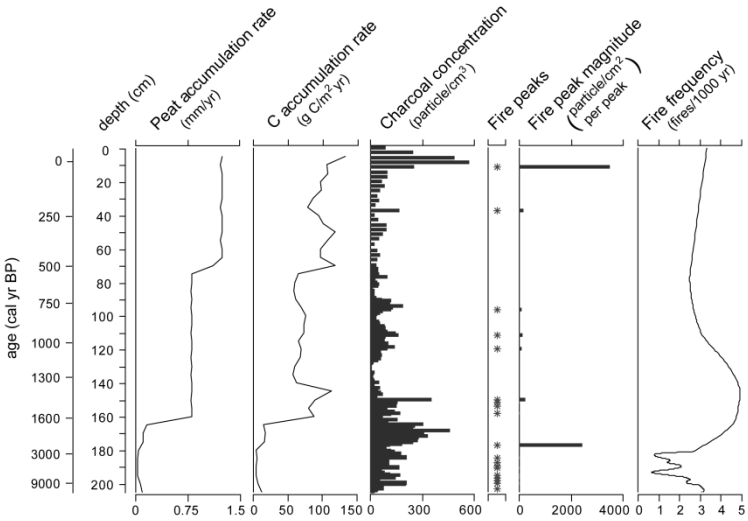


Diagram of peat accumulation rate, C accumulation rate, C_{org} and charcoal analysis results (Hapsari et al., submitted)

DISCUSSION

Based on the result, the vegetation in Sungai Buluh peatland was dominated by both peat swamp and mixed-riverine forest for over thousands of years throughout the record. Before the establishment of Muara Jambi temple or pre-1000 cal yr BP, the level of disturbance was minor. The disturbance indicator taxa such as Poaceae and *Ficus* intermittently present in low values.

After the establishment of Muara Jambi temple, or around 1000 cal yr BP, the peat-swamp taxa such as *Shorea*, *Durio*, and *Calophyllum* decreased. This was accompanied by the increase of Piperaceae, Poaceae and Grewioidea and followed by the decrease of Stemoniraceae and *Garcinia*, indicates the opening in the vegetation. Piperaceeae is a shade intolerant plant that usually grows in disturbed forest (Padmanaba and Sheil, 2014), Poaceae is commonly found as a result of forest clearance (Cole *et al*., 2014) and Grewioideae is pioneer vegetation in open and dry forest (Chung, 2005). The opening in forest vegetation was feasibly resulted from logging and timber harvesting. *Shorea, Durio* and *Calophyllum* trees are well-known timber plants and commonly used for constructions, boats and furniture (Soerianegara and Lemmens, 1994; Lemmens *et al*., 1995). Stemonuraceae and *Garcinia* trees are also used as timber. However, due to their lower quality, they are often considered as alternative timbers for tools and charcoal wood (Sosef *et al*., 1998).

The abundance of *Ardisia*, which grow rapidly on the grazing ground (Hoogerwerf, 1970) indicates that the inhabitant of Malayu Empire is also conducting grazing activities on peatland. The abundance of Piperaceae during the period of forest opening might provide benefit for the Malayu Empire. According to the historical record, Malayu Empire was a renowned pepper (*Piper* sp.) production center in Sumatra (Witrianto, 2014). This suggests that the population has also conducted wild-harvesting activities. The low fire frequency during Malayu Empire time suggests that the population did not use fire extensively for ground clearance or slash-and-burn. Moreover, lack of cultivation Poaceae in the pollen record also supports the argument that the inhabitant of Malayu Empire did not utilize the peatland for agricultural use. During the Malayu Empire time, the C accumulation rate was decreasing around 30%. The decrease of C accumulation might be related to the change in vegetation composition. As the forest cover decreased, the ecosystem received less lignin organic material. This accelerated the decomposition process and released carbon.

In the 14th century, after the conquest of Majapahit, Malayu Empire was ruled by an official court of Majapahit namely Adityawarman. The Empire became a vassal from Majapahit until Adityawarman declared his independence then moved the kingdom to Saruaso, a hinterland area in West Sumatra (Witrianto, 2014). After the abandonment of the site, the pollen evidence showed that the forest started to recover. The ability of forest to regenerate indicates that the ecological threshold has not yet been crossed by the level of disturbance. The regeneration process started with the increase of Poaceae and Grewioideae (Chung, 2005; Sutomo *et al.*, 2011) and followed by Stemonuraceae, *Calophyllum, Garcinia*, and later *Durio,* while *Shorea* seems not to be able to reach the pre-disturbance condition. Following the recovery of the forest, the value of C accumulation rate also recovered. As the intake of lignin organic material also increased and the decomposition rate was impeded, the carbon release through the decomposition process can be hindered. The forest regeneration process took around 100 years before the total proportion of both peat-swamp and mixed-riverine forest reached the pre-disturbance condition. This condition lasted for around 200 years before the level of disturbance re-increased around 100 yr cal BP.

The increase of *Ficus* was feasibly related to the rubber tree planting by local people as an obligation from the colonial governance. Local rubber plant, *Ficus elastica*, was commonly planted before *Hevea brasiliensis* was introduced in the 20th century. The increase of Piperaceae might also be related to the growth of pepper plantation under the colonial state (Karmela, 2014). Pepper was one of the important commodities of Jambi since the era of Jambi sultanate in 17th century. The increase of fire peak magnitude around 30 cal yr BP followed by abrupt increase of *Nephrolepis* and *Stenochlaena* around 10 cal yr BP was feasibly related to the intensive fire use for land clearance under colonial state. Around that time, the local people simultaneously convert their *ladang* into permanent rubber plantation. *Ladang* is a kind of field or farm that is commonly used for planting cassava, corn or different kinds of vegetables. Following the growth of the vehicle industry, the demand for rubber was increasing (Feintrenie and Levang, 2009). This condition escalated the rubber price in the market and encouraged the local farmers to switch from swidden to plant rubber and led to double rubber boom in 1920s and 1930s (Feintrenie and Levang, 2009).

CONCLUSION

Some important information could be asserted from the palaeo study of the natural archive of Sungai Buluh peatland. Albeit the lack of instrument and technology, excessive anthropogenic activities on tropical peatland began already over a million years ago. This result suggests that human impact on peatland is not a recent phenomenon. However, compared to modern land use, the human activities on peatland in the past might restricted to logging, grazing and wild harvesting, without involving extensive fire use and cultivation. Such activities changed the vegetation composition and decreased the ecosystem ability to accumulate carbon. Even without conducting large-scale peatland burning or conversion, human still can affect the ecological function of peatland. Nonetheless, this study shows that peatland can be resilient to excessive human disturbance. The vegetation and C accumulation rate of Sungai Buluh peatland have recovered, taking around 100 years after the cessation of disturbance following the site abandonment. This provides an overview of what kind of disturbances that could be reversed. The past socioeconomic condition during the period of the colonial state are also recorded in the Sungai Buluh archives. The trading commodities, industrial needs and population‘s wealth are captured by the natural archives. It shows that beside the direct anthropogenic activities, socioeconomic condition is also an important indirect driver of peatland disturbance. This information could define the past disturbances and its impact on the peatland. Furthermore, this also enhanced the understanding of the recovery process as well as the required time of the process. Therefore, in order to maintain the function and sustainability of peatlands, it is important to involve different perspectives throughout consideration regarding decision for peatland management, including palaeoecology that delivers the message from the past.

ACKNOWLEDGEMENTS

We thank Dorothee Dashbach (Chemilabor, ZMT Bremen) for supporting the carbon content measurements. The research is conducted using samples collected under Research Permit No. 1095/FRP/SM/V/2013 recommended by the Indonesian Institute of Science (LIPI) issued by the Ministry of Forestry (PHKA). The financial supports are provided by the DFG Sonderforschungsbereich in CRC 990 (EFForTS) subproject A01 and Erasmus Mundus Lotus Program. We acknowledge also the financial support from Göttingen International for attending the conference.

REFERENCES

1. Anderson, J.A.R., Muller, J., 1975. Palynological study of a holocene peat and a miocene coal deposit from NW Borneo. Review of Palaeobotany and Palynology 19, 291–351.
2. Anshari, G., Kershaw, A.P., van der Kaars, S., 2001. A Late Pleistocene and Holocene pollen and charcoal record from peat swamp forest, Lake Sentarum wildlife reserve, West Kalimantan, Indonesia. Palaeogeography, Palaeoclimatology, Palaeoecology 171, 213–228.
3. Birks, H.J.B., 2012. Ecological palaeoecology and conservation biology : controversies, challenges, and compromises. International Journal of Biodiversity Science, Ecosystem Services & Management 8, 292–304.
4. Chung, R.C.K., 2006. Revision of Grewia (Malvaceae–Grewioideae) in Peninsular Malaysia and Borneo. Edinburgh Journal of Botany 62, 1.
5. Cole, L.E.S., Bhagwat, S.A., Willis, K.J., 2014. Recovery and resilience of tropical forest after disturbance. Nature Communication 5, 3906.
6. Cole, L.E.S., Bhagwat, S.A., Willis, K.J., 2015. Long-term disturbance dynamics and resilience of tropical peat swamp forests. Journal of Ecology 103, 16-30.

7. Faegri, K., Iversen, J., 1989. In: Textbook of Pollen Analysis, revised by Faegri, K., Kaland, P.E., Krzywinski, K. John Wiley, New York.
8. Feintrenie, L., Levang, P., 2009. Sumatra‘s rubber agroforests: Advent, rise and fall of a sustainable cropping system. Small-scale Forestry 8, 323–335.
9. Hapsari, KA., Biagioni, S., Jennerjahn, T., Reimer, P.M., Saad, A., Sabiham, S., Behling, H., submitted manuscript.
10. Hoogerwerf, A., 1970. Udjung Kulon: The Land of the Last Javan Rhinoceros. E.J. Brill, Leiden.
11. Jones, S.E., Pearce, K.G., 2015. A pollen morphology study from the Kelabit Highlands of Sarawak, Malaysian Borneo. Palynology 39, 150–204.
12. Juggins, S., 2007. C2 user guide: Software for ecological and palaeoecological data analysis and visualization. University of Newcastle, UK.
13. Karmela, S.H., 2014. Kehidupan ekonomi penduduk dalam setiap periodisasi sejarah Jambi. Jurnal Ilmiah Dikdaya 4, 1.
14. Lemmens, R.H.M.J., Soerianegara, I., Wong, W.C., 1995. Plant Resources of South-East Asia No. 5(2). Timber trees: Minor commercial timbers. Prosea Foundation, Bogor, Indonesia
15. Padmanaba, M., Sheil, D., 2014. Spread of the invasive alien species *Piper aduncum* via logging roads in Borneo. Tropical Conservation Science 7, 35-44.
16. Soerianegara, I., Lemmens, R.H.M.J., 1994. Plant Resources of South-East Asia No. 5(1). Timber trees: Major commercial timbers. Prosea Foundation, Bogor, Indonesia.
17. Sosef, M.S.M, Hong, L.T., Prawirohatmodjo, S.,1998. Plant Resources of South-East Asia No. 5(3). Timber trees: Lesser-known timbers. Prosea Foundation, Bogor, Indonesia.
18. Sutomo, S., Fardila, D., Putri, L.S.., 2011. Species composition and interspecific association of plants in primary succession of Mount Merapi, Indonesia. Biodiversitas, Journal of Biological Diversity 12, 212–217.
19. Witrianto, 2014. Potensi sejarah dan purbakala DAS Batanghari. Analisis Sejarah 5, 68–79.
20. Yulianto, E., Hirakawa, K., 2006. Vegetation and environmental change in the early - Middle holocene at a tropical peat swamp forest, Central Kalimantan, Indonesia. Tropics 15, 65-73.