Dynamics of Soil Organic Matter in Tropical Peatland

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Abstract

Peatland stores a huge amount of carbon (C) and has been involved in the global C cycle as a C sink. Approximately 440,000 km^2 of peatland area exist in tropics under different forest types. The quality of peat soil organic matter (SOM) with regard to the stability after land use change is expected to be various. Thus, the present study aimed to evaluate the dynamics of SOM in tropical peat soils that have been developed in different types of forests under natural environmental conditions and artificially modified environmental conditions for agricultural use. In Chapter 2, to elucidate the variations in the chemical structure of SOM in tropical peat soils as a function of time that are resulted from the different rate of peat accumulation and different C source (vegetation), peat soil core samples were collected from several depths in three representative peat swamp forests in Sarawak, Malaysia, i.e., Mixed Peat Swamp (MPS), Alan Batu (ABt), and Alan Bunga (ABg) forests, and their ^{14}C ages were determined and their ramp ^{13}C cross polarization/magic angle spinning (CPMAS) nuclear magnetic resonance (NMR) spectra were analyzed. ^{14}C ages of the bottom peat layers indicated that the Maludam peat dome formation began in ca 5,000 yBP in the current MPS forest. The rate of peat accumulation are in the order ABg (0.18 cm yr^{-1}) > ABt (0.16 cm yr^{-1}) > MPS (0.07 cm yr^{-1}). The decrease in the rate of peat accumulation in the MPS forest site resulted in distinct changes in SOC composition, notably, a relative increase in alkyl C with decrease in *O*-alkyl C. In Chapter 3, to evaluate the variations in the decomposability of tropical peat soils following deforestation for an oil palm plantation (OPP), soil samples were collected from the MPS, ABt, and ABg forests in the Maludam National Park, packed in PVC pipes, and incubated in the Naman OPP in Sibu, Sarawak, from August 2012 to August 2015. CO_2 and CH_4 fluxes from soil, and groundwater table were monthly measured. SOC composition estimated from ^{13}C CPMAS NMR spectra with phase-adjusted spinning side bands (PASS) sequence was also determined for the initial soil samples. In the C composition, the relative abundance of alkyl C (21–33%) was greater in the order MPS, ABt, and ABg, while that of *O*-alkyl C derived mainly from

polysaccharides (26–37%) was in the opposite order. Both total CO_2 and CH_4 fluxes were larger in the order ABg > ABt > MPS. Based on the cumulative amount of CO_2 flux and the change in amount of organic C in the pipes, it was estimated that 6.4–9.7% (MPS), 14.0–14.5% (ABt), and 17.2–17.6% (ABg) of SOC was lost during the 3-year period. These differences seem to reflect the difference in the labile organic matter content, represented by polysaccharides. In Chapter 4, to evaluate the variation in the sensitivity of SOM in the surface peat soils to environmental changes induced by managements for agricultural use, soil incubation experiments with increasing pH and temperature and photodegradation experiments using a solar simulator were conducted. A total of 20 soil samples (0–25 cm depth) were collected from primary forests, OPPs, sago palm gardens (SGs), and secondary forests nearby the OPPs or SGs in 6 sites (Maludam, Betong 1 and 2, Naman, Talau, and Mukah) in Sarawak. ^{13}C CP/PASS NMR spectra were obtained for all the samples. 13 soil samples were incubated in Erlenmeyer flasks with W-rubber stopper for 91 days under dark conditions using 3 treatments: Control (native pH (ca. 3), 25°C), Neutral pH (pH was regulated at 7; 25°C), and High temperature (native pH, 35°C). 14 soil samples (5 mm thickness) were also irradiated at 650 W m^{-2} at 35°C for 7 days. % aromatic C were lower in forest soils than in OPP or SG soils, while no difference was observed in the rate of SOC mineralization in all the three treatments in the biodegradation experiments. The increase in temperature enhanced SOC mineralization with Q_{10} of 1–2. Various types of responses were observed against neutralization. The 7-day irradiation decomposed 2–19% of SOC, suggesting the acceleration of loss of peat SOM. No difference in the persistency to irradiation was observed between land use or forest type, and no notable change in SOC structure was suggested. In conclusion, this study revealed that there are variations in the process of peat growth and chemical characteristics of SOM corresponding to present vegetation for the tropical peat soils in Sarawak, Malaysia, and that there are no differences in the sensitivity to the increased pH, increased temperature, and irradiation between forest and OPP or SG soils more than 5 years after land use change. Based on these findings, it is considered that mineralization of SOM progresses abruptly and continuously after land development with accompanying construction of drainage canals, particularly in ABt and ABg forests. Therefore, it is suggested that types of forests must be carefully selected and managed for developing them as agricultural land.