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Soil organic matter chemistry changes upon secondary succession in *Imperata* Grasslands, Indonesia: A pyrolysis–GC/MS study

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ABSTRACT

The chemical composition of soil organic matter (SOM) following secondary succession in *Imperata* grassland was investigated by Pyrolysis-Gas Chromatography/Mass Spectrometry (GC/MS). We studied 46 samples from different stages of succession using plots that last burned 3 and 9 years previously, secondary forest (≥15 years), primary forest and *Acacia mangium* plantation (9 years). During regeneration of *Imperata* grasslands the chemical composition of SOM changes considerably. Differences between litters and SOM were larger than within SOM, which is mainly due to a rapid degradation of lignin in the soil. Both litter and SOM under *Imperata* contain larger amounts of carbohydrates and fewer lignin moieties, aliphatics and N-compounds than those under secondary and primary forest. Nevertheless, SOM degradation under grassland is less efficient because of scarcity of N-compounds. SOM decomposition is most advanced under forest, as indicated by lower amounts of plant derived compounds and higher contribution of microbial matter. Decomposition efficiency appears to be related to SOM chemistry, but more to abundance of N-compounds than to that of potentially recalcitrant compounds. C stocks were linked to decomposition efficiency and litter production.

1. Introduction

Regeneration of grassland areas is becoming increasingly important, both to create new secondary forest and to recover the original biodiversity. In previous papers was shown that, during regeneration of *Imperata* grasslands, both vegetation composition and soil properties change, including carbon stocks. We found that the effects of regeneration on soil were strongest in the A-horizon, where an increase in carbon stock, N stock, and C/N ratio, and a decrease in bulk density and pH were observed. Soil carbon stocks increased upon natural regeneration from grassland to secondary forest; highest carbon stocks were found in the later regeneration stages and lowest under primary forest (Van der Kamp et al., 2009; Yassir et al., 2010). Because soil carbon stocks were lower under primary forest than under *Imperata* grasslands, the question arises whether such differences are due to chemically different litter inputs and/or different decomposition efficiency. Such insight may help to predict soil carbon changes in relation to climate and vegetation change.

In Indonesia, most studies focussed on soil carbon quantity changes in relation to land use change (Lal and Kimble, 2000; Ohta et al., 2000; Van der Kamp et al., 2009; Van Noordwijk et al., 1997; Woomer et al., 2000). No studies exist on the chemical composition of soil organic matter in relation to land use changes in Indonesia, but some studies using ^{13}C NMR or pyrolysis-GC/MS exist for temperate areas (Dorado et al., 2003; Mendham et al., 2002; Nierop et al., 2001a; Römkens et al., 1998). Studies for tropical areas are scarce. Buurman and Roscoe (2011) studied soil organic matter chemistry in cultivated fields and Brazilian cerrado, and compared cultivation practices. Such studies have been linked to SOM dynamics, through which relations with SOM stocks should be expected.

Pyrolysis-GC/MS provides a large amount of structural information on SOM (De la Rosa et al., 2008; Hatcher et al., 2001; Parsi et al., 2007; Saiz-Jimenez and De Leeuw, 1986), and better identification and comparison of the SOM produced under different environments (Lienweber and Schulten, 1999; Nierop et al., 2001b; Perobelli Ferreira et al., 2009; Saiz-Jimenez et al., 1996). It also provides information on, e.g., selective decomposition and preservation of plant-derived material, admixture of microbial products, and addition of charred material (Buurman and Roscoe, 2011; Buurman et al., 2007b; Kaal et al., 2008). We have therefore chosen to use this method to describe the chemical composition of SOM following secondary succession in *Imperata* grasslands. We collected and analyzed samples from different stage of secondary succession, primary forest, and *Acacia mangium* plantation (9 years). The objective of this study was to improve our understanding of the relations between vegetation, SOM chemistry, and SOM stock.

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2. Materials and methods

2.1. Study area

The study areas Sungai Wain and BOS Samboja Lestari are situated in East Kalimantan, Indonesia (Fig. 1). Sungai Wain is a unique protected forest of about 10,000 ha that contains one of the last unburned primary forests of the Balikpapan — Samarinda area (Whitehouse and Mulyana, 2004). Samboja Lestari is a 1,850 ha reforestation project owned by the Borneo Orangutan Survival Foundation (BOS). Plots selected for the analysis of regeneration impacts are situated at Samboja Lestari, whereas the primary forest plots from Sungai Wain function as a control. The Köppen system classifies the climate of the research area as Af (Tropical Rainforest). Average yearly precipitation is 2250 mm, with a wet period from December to May. The driest month has an average precipitation of 132 mm, and the wettest month of 231 mm. The daily maximum temperature varies from 23 °C to 31 °C and relative humidity is high. The soils in both areas are formed on marine sediments. Topsoils are generally slightly coarser than the deeper layers. In the FAO classification system (FAO, 2001) the soils of Samboja Lestari and Sungai Wain classify as Acrisols. Nutrient levels are low, especially that of available phosphorus; pH values vary between 4.09 and 4.55 (Yassir and Omon, 2006).

2.2. Data collection

All field data were collected in the areas of Samboja Lestari and Sungai Wain. A classification of plots in Samboja Lestari was based on the fire history and succession stage (Van der Kamp et al., 2009). 46 samples from different stages of succession were analyzed, using plots that last burned 3 and 9 years previously, secondary forest (≥15 years of regeneration), and primary forest. *A. mangium* plantations are the main production forests in this area, and at Semboja Lestari we observed a profound change of soil color under this vegetation. We therefore included soil and litter samples of a 9-year old *A. mangium* plantation. In addition to litter, soil samples were taken of the A-, AB- and B-horizon. The AB-horizon was absent under primary forest and under *A. Mangium*. Methods of soil analysis were listed in detail by Van der Kamp et al. (2009). The descriptions of soil properties and vegetation dominances in sampling plot are summarized in Table 1.

2.3. Organic matter extraction

Soil organic matter was extracted according to the standard protocol of the International Humic Substances Society. In short, five g of air-dried soil sample (<2 mm) was extracted with 50 mL of 0.1 M NaOH and shaken during 24 h under N_2 atmosphere to prevent oxidation. The suspension was centrifuged at 4000 rpm during 1 h and the extract was decanted. The extraction was repeated. The two extracts were mixed and the residue was discarded. The extracts were acidified to pH 1 with concentrated HCl to protonate SOM. One mL of concentrated HF was added to dissolve silicates and increase the relative content of organic C of the extracted fraction. The acid mixture was shaken for 48 h, after which it was dialyzed to neutral pH against distilled water to remove excess salt, using dialysis membranes with a pore diameter of 10,000 Da. The solution was then freeze-dried. Litter samples were washed to remove adhering soil, dried at 40 °C during 48 h, finely crushed in a mill, and pyrolysed.

2.4. Pyrolisis–GC/MS

Curie-point pyrolysis was carried out using a Horizon Instruments Curie Point Pyrolyser (Horizon Instruments, Heathfield, UK). Freeze-dried SOM extracts and litter samples were pressed on Curie point

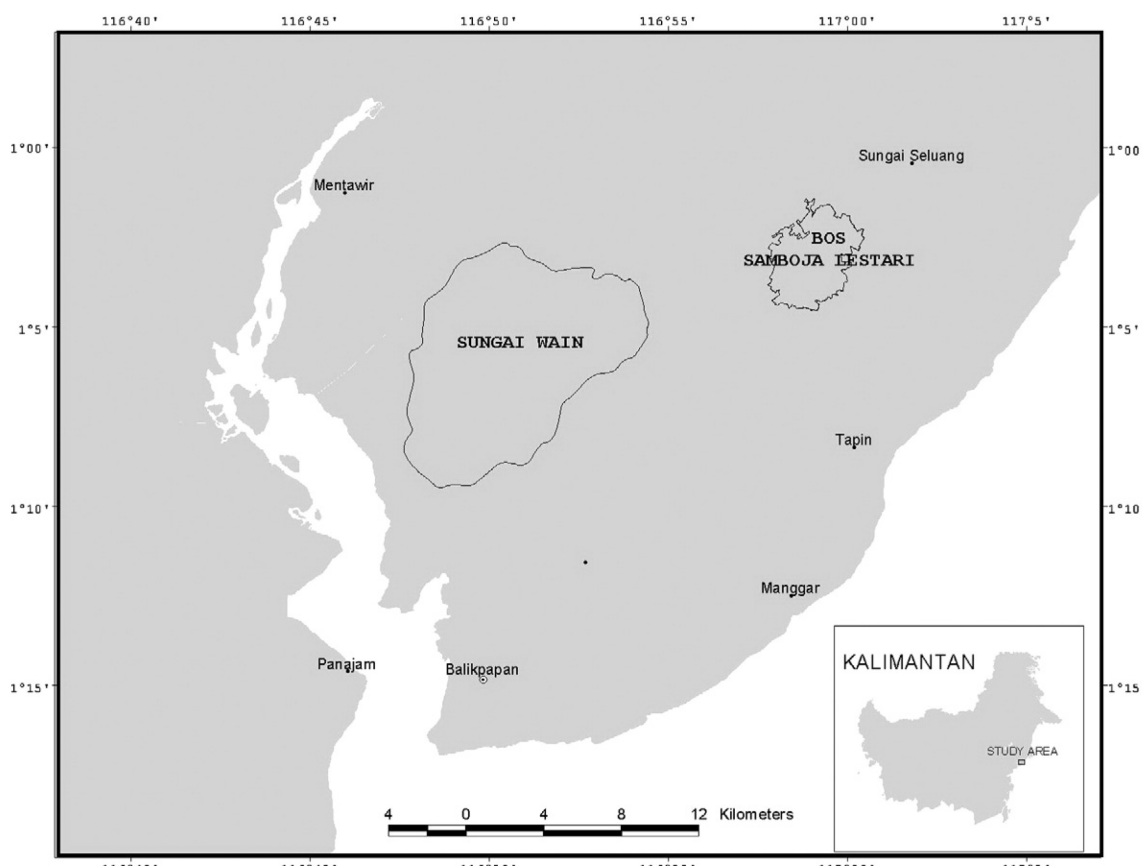

Fig. 1. Location of Sungai Wain protection forest and BOS Samboja Lestari.