



Comparison of soil macro-invertebrate communities in Malaysian oil palm plantations with secondary forest from the viewpoint of litter decomposition



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ARTICLE INFO

Article history:

Received 26 May 2016

Received in revised form 2 September 2016

Accepted 12 September 2016

Available online 19 September 2016

Keywords:

Deforestation

Earthworms

Management practice

Microhabitats

Termites

ABSTRACT

Biodiversity decline in rapidly expanding oil palm plantations is of global concern. Many studies have demonstrated that fauna species diversity is lower in oil palm plantations than forests. However, information about the flow-on effects of these declines in species diversity on ecosystem functioning is scarce for oil palm plantations. Litter decomposition performed by soil organisms is a vital ecosystem function that regulates nutrient cycling and carbon sequestration. Some studies have found a high level of redundancy among litter decomposing species. In order to evaluate the effects of the conversion of forests to oil palm plantations on decomposition, we investigated the abundance and biomass of soil macro-invertebrates at sites in two oil palm plantations and a secondary forest in Malaysia. Biodiversity of soil macro-invertebrates were lower in the oil palm plantations than in the secondary forest. The abundance and biomass of surface-living litter transformers was lower in oil palm plantations than forest, probably due to the isolated piles of frond litter that occur in plantations, instead of the more continuous litter layer observed in forests. However, we found dense populations of wood (litter)-feeding termites in the thick rachises of fronds heaped on the ground surface. A pantropical earthworm species, *Pontoscolex corethrurus*, which buries the litter through cast deposition, abounded more in the oil palm plantations than in the secondary forest. These characteristics of soil macro-invertebrates have also been reported in other oil palm plantations. Thus, we conclude that the conversion of forests to oil palm plantations may reduce diversity of soil macro-invertebrates, increase the heterogeneity of macro-invertebrates distribution and decrease populations of some functional groups of soil macro-invertebrates. However, overall, forest conversion does not appear to have a negative impact on the decomposition process to a great extent, owing to the colonization of plantation sites by other groups of decomposer animals that are favored by disturbance and/or the great amount of localized input of fresh fronds pruned at the time of fruit harvesting.

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1. Introduction

To date, most of the major oil palm plantations comply with an international certification system that sets voluntary standards for producers and provides assurances to consumers, such as the Roundtable on Sustainable Palm Oil, one of the aims of which is to reduce the impact of deforestation on ecosystem services

(RSPO Principles and Criteria Review, 2011/2012). However, rapid expansion of oil palm plantations in recent decades has been widely criticized for deforestation in the tropics, especially in Southeast Asia (Singh and Bhagwat, 2013), one of the world's most biodiverse regions (Sodhi et al., 2010). As reviewed by Fitzherbert et al. (2008) and Savilaakso et al. (2014), conversion of forests, whether intact or disturbed, to oil palm monocultures reduces species richness across a wide range of animal taxa. In view of this, much effort has to be put on the research that promotes balance between cultivation of oil palm and biodiversity conservation

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(Turner et al., 2011). At the same time, comparable efforts should be made to evaluate the consequences of reduced biodiversity for ecosystem functions.

Although there is almost no study that seeks to relate biodiversity and ecosystem services in oil palm plantations (Foster et al., 2011; Savilaakso et al., 2014), the reduction in species richness of the above-ground animals is expected to impoverish those ecosystem functions, such as pollination, seed dispersal, and biological pest control, that strongly depend on species-to-species relationships. However, it is not necessarily obvious whether decomposition, an ecosystem function that regulates nutrient cycling and carbon sequestration, is adversely affected to a similar extent by reduced richness of soil invertebrate species, since there is a high level of species redundancy among litter decomposers (Andren et al., 1995), and decomposition is considered to be less species specific (Kurokawa and Nakashizuka, 2008) than the functions mentioned above. For example, Foster et al. (2011) did not find any significant difference in litter mass loss in litterbags between a primary forest, logged forest, and oil palm plantation, owing to the activities of a single species of the widespread termite *Macrotermes gilvus* in the plantation.

In contrast to the general declining trend in faunal diversity with increasing simplification of the flora, abundance and/or biomass of animals is not always depressed in disturbed systems including oil palm plantations (Foster et al., 2011; Savilaakso et al., 2014) often due to colonization by a few generalist- or cosmopolitan-species with high environmental tolerances and high potential of population growth. In this context, despite confining ourselves only to comparing the soil macro-invertebrates in primary forests and tree plantations in humid tropical areas, we find sufficient evidence demonstrating that the abundance and/or biomass in the tree plantations is more than that in primary forests: earthworm abundance and biomass in Peru (peach palm, *Bactris gasipaes*; Lavelle and Pashanasi, 1989), abundance of beetle larvae, isopods, moth larvae, and cockroaches in Brazil (*Acacia mangium*; Pellens and Garay, 1999), biomass of earthworms, harvestmen, isopods, and whole soil macro-invertebrates in Sarawak (*Acacia mangium*; Tsukamoto and Sabang, 2005), isopod abundance in Sabah (oil palm, *Elaeis guineensis*; Hassall et al., 2006), and so on. Therefore, it is possible that the functional role of soil macro-invertebrates is not necessarily lower in tree plantations than in primary forests in the tropics.

One of the most noticeable environmental characteristics that litter and soil animals experience in oil palm plantations is the alternating pattern of frond heaps and bare ground, brought about by localized input of fresh fronds pruned at the time of fruit harvesting, rather than the continuous litter layer formed by homogeneous input of senescent leaves. In an oil palm plantation, the distribution of soil macro-invertebrates was reported to be significantly affected by this habitat heterogeneity (Carron et al., 2015). Therefore, an estimate of the abundance and/or biomass of soil macro-invertebrates and an evaluation of their functions in oil palm plantations should be performed after taking into account this habitat heterogeneity.

Several recent studies have quantitatively investigated soil macro-invertebrate communities in oil palm plantations in relation to soil quality (Lavelle et al., 2014; Carron et al., 2015) and the resulting energy flux through such communities (Barnes et al., 2014). However, no studies have fulfilled all of the following conditions needed to evaluate the functional role of soil macro-invertebrates in oil palm plantations: macro-invertebrate collection in both the surface litter and the underlying soil; stratified sampling taking habitat heterogeneity into consideration; and measurement of both the abundance and biomass of individual functional or taxonomic groups.

We studied the abundance and biomass of soil macro-invertebrates in the litter and mineral soil in two oil palm planta-

tions of different planting ages in Tekam, Malaysia, taking into account three different microhabitats caused by management practices: weeded circle, harvest path, and frond heap. A neighboring secondary forest with a closed canopy was selected as a control forest site that was disturbed but with a continuous layer of litter.

Our goals were (1) to describe soil macro-invertebrate communities in oil palm plantations compared with secondary forest using measures that, unlike previous studies, allow for an assessment of the functional role of these communities, and (2) to use this assessment to determine the most plausible evaluation how the conversion of forests to oil palm plantations might affect the decomposition of frond piles on the forest floor.

2. Material and methods

2.1. Study site

The study was carried out in 2012 at an oil palm plantation in Tun Razak Agricultural Research Centre in Jengka Triangle, 1750 ha in area, situated on undulating terrain at an altitude of 45–75 m a.s.l. along the Pahang River; in the state of Pahang, Malaysia. The annual mean temperature is 27.4 °C, and the average annual precipitation is 2097 mm without a distinctive dry season (Tekam Meteorological station, 10 years average from 2003 to 2012). According to the Department of Mineral and Geoscience Malaysia, the Jengka Triangle exhibits largely Triassic-Jurassic geology, but older rocks from the Permian were also found. Most of the rocks originated from the volcanic rock consisting of prominent lava flows, tuffs and agglomerates of andesitic and rhyolitic composition. At the study site, the soils have derived from quartz diorite or quartz andesite (Paramanathan, 2000). Two oil palm plantations of different planting ages, 5 and 18 years after conversion from cocoa plantations, 33.2 and 60.7 ha in area, respectively (N3°54'17.6" E102°31'28.6"), were selected from the areas of almost flat terrain. The operational procedures in both of the conversion from forests to cocoa plantations and from cocoa plantations to oil palm plantations included logging, bulldozing, and burning. A neighboring secondary forest with a closed canopy, 8.8 ha in area (N3°52'16.2" E102°30'59.6"), was selected as a control forest site. They were given habitat-codes of OP5, OP18, and SF, respectively.

Soil fertility status in the study sites has been discussed by Yusuyin et al. (2015, 2016) and Tan et al. (2014, 2015) in relation to the same microhabitats as those in the present study: weeded circle, harvest path, and frond heap.

2.2. Microhabitats

Commercial oil palm trees (*Deli dura* × *Yangambi pisifera*) were planted in equilateral triangular arrangement with a distance of 9.1 m between each tree and at a density of 136 trees ha⁻¹. The following three microhabitats were distinguished and designated by a microhabitat-code, WC, HP, and FH. WC (weeded circle) is a circle area 1.5 m in radius from each tree trunk. This microhabitat receives herbicides and inorganic fertilizers periodically and has exposed ground surface except when a pile of fruit bunches is sometimes formed during the harvesting operation. The area between two adjacent rows of planted trees is alternately used for passage and as a depositing place for fronds that are pruned at the time of fruit harvesting. HP (harvest path) is the passage area where no frond litter is supplied and lacks the surface litter layer, although the ground surface is covered with soft grass. FH (frond heap) is the area stacked with oil palm fronds. In a 20-year-old oil palm plantation with a density of 143 palms ha⁻¹, planted in an equilateral triangular arrangement at a distance of 9 m, the

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