E-3.1 Effects on soil formation and soil structure of disturbance in tropical forest

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Total Budget for FY1996-FY1998 35,547,000 Yen (FY1998; 11,767,000 Yen)

Abstract Abundance of termites and wood decay fungi as decomposers were censused in natural and regenerate forests of the Pasoh Forest Reserve, a lowland rain forest of peninsular Malaysia to reveal mechanisms maintaining the decomposer community and assess effects of logging on soil formation. Seedlings of *Shorea macroptera* were planted in enclosures where termites were excluded in order to assess the role of decomposition by termites in tree growth.
(1)Fungal species occurring on woody substrata were affected by the substratum conditions as diameter, tree species and decomposition process. More species were found in natural forest compared with regenerate forest which suggests that logging may reduce the diversity of wood decay fungi.
(2)In both forests, a fungus-growing termite *Macrotermes malaccensis* was the most dominant among the wood-foraging termites whose diversity was higher in natural forest. A processional termite of the genus *Hospitalitermes* preferred large-sized trees as a foraging site and nested more densely in natural forest where large trees were more numerous.
(3)Termite-removal experiment did not succeed, but suggested that experimental removal should be undertaken not with seedlings, but with naturally-grown trees for functionally-dominant termites.

Key Words Logging, Wood litter, Termite, Wood decay fungus, Tree fall gap

1.Introduction

Decomposer organisms utilize plant litter on the forest floor as an energy source. On the process, they release nutrients to the environment by fragmenting, deteriorating or digesting plant litter. On the other hand, they generate soil mass and structure by degrading and supplying litter residue as soil component and forming interspace in the soil through their digging or penetrating. Nutrient release is advantageous to forest trees in enhancing their growth. Soil generation is favorable to forest trees in increasing water permeability and retention ability. Thus, decomposer organisms are important in sustaining tropical forest ecosystem and its environment.

Logging practice as disturbances not only damages trees, but also destroys soil environment. Decomposers will be also affected by these disturbances. For example, occurrence of wood decay fungi reflects the conditions and distribution of woody substrata. How strong and long these effects are sustained is an important point in rehabilitation of logged tropical forests. Knowledge on how much decomposer organisms are in the forest ecosystem and what role they play there are necessary to assess the effects of logging on these organisms. We know what organisms play the role of decomposers and which organism takes the major part of it about those decomposing leaf litter, but not about decomposers of wood litter. Such information is important to understand logging effects.

2.Research objectives

In the present study, we investigated the distribution of termites and wood decay fungi in natural and regenerate forests. By doing this, we intended to know how many species and what amount of these decomposers occur in those forests and what conditions generate the difference of flora and fauna between these forests. A further objective was to reveal what are the effects of logging on these decomposers and their function. This kind of knowledge will contribute to recovering forest environment after logging.

3. Materials and methods

A study area was selected in the Pasoh Forest Reserve, Khusus District, Negeri Sembilan, Malaysia. This area covered natural and regenerate forests including research plots mentioned afterwards.

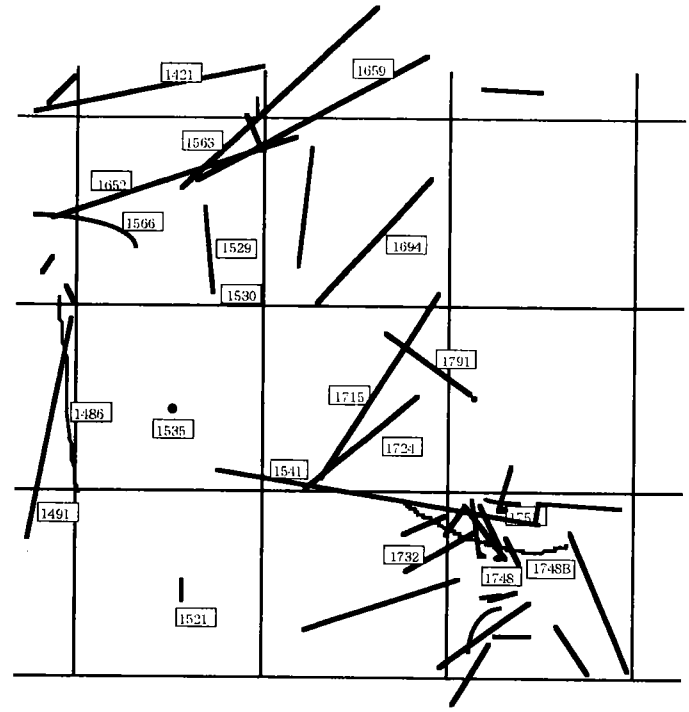

Fig. 1. Part of a wood-litter map. One grid is 20 m by 20 m; numerals in squares are individual numbers of wood litter.

(1)Fungal host specificity

Wood decay fungi were recorded occurring on fallen trees whose scientific names were already determined in the study area. Wood blocks were collected from fallen trees with some wood decay fungi, then tree genera or families were determined by examining the samples by microscope.

(2)Succession of wood decay fungi

Twenty nine trees fallen in 1992-1995 were marked and then wood decay fungi occurring on these trees were recorded once or twice a year.

(3)Comparison of fungal flora between natural and regenerate forests

Plots of natural and regenerate forests were located in the study area. The natural plot was 100 m both from north to south and from east to west. This plot was originally set as a southern half of Plot 1 (200 m by 100 m) for tree census. The regenerate plot where selective logging was done in 1958-1959 was set 300 m north of the natural one in the same size. Both plots were divided into 100 sub-plots (10 x 10 m).

Wood litter as fallen trees, branches, etc. was measured in size. Those longer than 2 m and wider than 10 cm in diameter were marked individually (Fig. 1) and sub-sampled for taxonomical identification. Wood decay polypores were recorded from marked ones.

(4)Dynamics of fungal flora after massive tree falls

Plot 1 (200 x 100 m) were divided into 200 sub-plots (10 x 10 m). Each subplot was categorized into those with massive tree falls in June and July, 1995 (95G, 29 sub-plots), those with tree falls in the period from 1992 to the massive tree falls in 1995 (92G, 12 sub-plots) and those without tree falls (NG, 159 sub-plots). Wood decay fungi occurring in each subplot were recorded in August, 1995 and December of 1995, 1996, 1997 and 1998.

(5)Wood-foraging termite

Termites were collected from the marked wood litter in the natural and regenerate forest plots. In sampling, wood litter was bored, cut or cleared of soil cover partly. Soldier and worker termites found were collected and put in nearly pure ethanol. They were dissected under a stereoscopic binocular and their morphological characters such as head length, head width, body color and mandible form were recorded. Their taxonomical identities were determined according to a book "Termites of Peninsular Malaysia" by Tho Yow Pong.

Termites were also collected from wood litter of less than 10 cm in diameter in other parts

of natural and regenerate forests. At a site in either natural or regenerate forest, these wood litter were located and broken to small pieces to find termites.

(6)Processional termites

Processional termites of the genus *Hospitalitermes* were censused about nest and foraging place. Starting at around 8:00 AM, processions of these termites were explored and followed to nests and foraging sites in plots. Positions and sizes of tress where nests were constructed or termites were foraging on lichen, moss, bark, etc on their trunks were recorded.

(7)Tree growth in termite exclusion

In order to evaluate the role of termites in recycling nutrients in plant litter to trees, tree seedlings were planted in enclosures and control ones. Nine seedlings of *Shorea macroptera* in height of about 50-80 cm were planted in one enclosure. A pair of a termite-free and a control enclosures was set at eight sites in regenerate forest. For two years, their statures were measured three to four times per year.

4.Results and discussion

(1)Host specificity

A total of 680 wood decay fungi on 318 substrata belonging to 35 families and 84 genera were recorded in the research site. Among frequent-occurring species, following species were supposed to be generalists whose occurrence was not restricted on trees belonging to particular tree families: *Amauroderma parasiticum*, *Coriolopsis. retropicta*, *Ganoderma australe*, *Nigroporus vinosus*, *Phellinus noxius*, *Rigidoporus hypobrunneus*, *R. microporus*, *Schizopora* cf. *flavipora*, *Steccherícium seriatum*, *Tinctoporellus epimiltinus*, *Trichaptum durum*, etc.

Following species were restricted on dipterocarp trees, and supposed to be specialists on Dipterocarpaceae: *Daedalea aurora*, *Erythromyces crocicreas*, *Fomitopsis carnea*, *F. dochmia*, *Perenniporia dipterocarpicola*, *Phellinus* cf. *fastuosus*. Some of other species like *Nigrofomes melanopus*, *Phellinus lamaensis*, *Pyrofomes albomarginatus* also showed preference on dipterocarp trees. *Perenniporia hexagonoides* always occurred on living trees of *Scaphium macropodum*, and some species as *Earliella scabrosa*, *Daedalea* sp. No. 1 and *Loweporus*

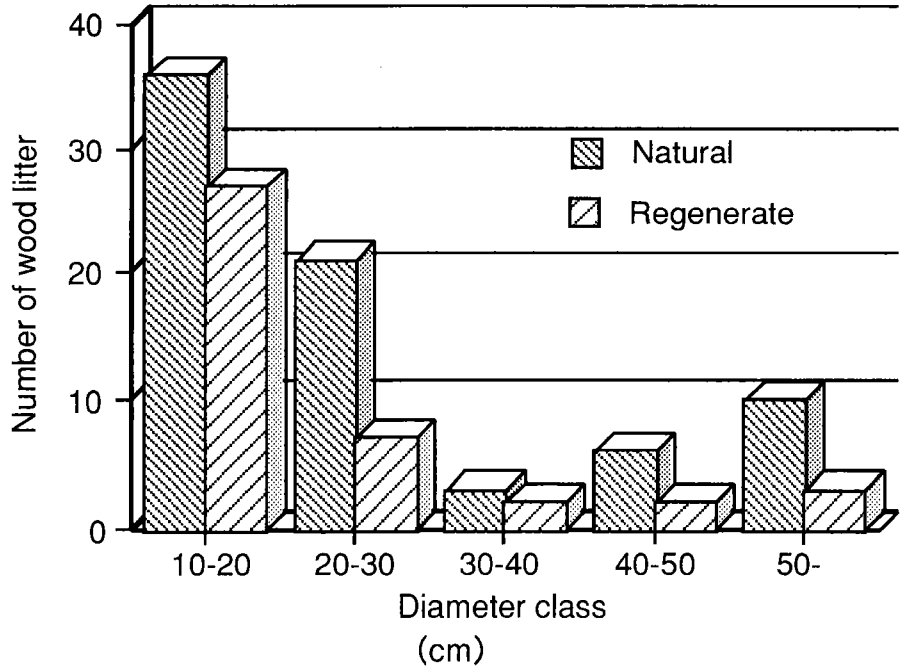

Fig. 2. Frequency distribution of diameter of wood litter in natural and regenerate forests

fuscopurpureus preferred trees of Euphorbiaceae.

(2)Succession of wood decay fungi

Some species of wood decay fungi as *Ganoderma australe*, *Schizopora* cf. *flavipora*, *Rigidoporus microporus*, etc. produced basidiocarps within 1-2 years after the tree falls, and supposed to be primary colonizers. *Nigroporus vinosus*, *Steccherícium seriatum* etc. produced basidiocarps on well-decomposed substrata and supposed to be secondary colonizers.

(3)Comparison of fungal flora between natural and regenerate forests

In the natural forest plot, a total of 76 fallen trees were marked, of which 10 trees were wider than 50 cm in diameter while, of 41 trees marked in the regenerate forest plot, only 3 were wider than 50 cm in diameter (Fig. 2). Most of the huge fallen trees in the regenerate plot were old dipterocarp trees.

A smaller number of species of wood decay fungi were found in the regenerate plot because there were less species of ramicolous fungi (those restricted on fallen twigs and branches) found in the plot.

(4)Dynamics of fungal flora after massive tree falls

In sub-plots of 95G, the number of fungal species increased in December 1996, then slowly decreased while no fluctuation was seen in NG sub-plots. The occurrence of ramicolous fungi in 95G hardly differed with that in NG, but the frequency and species number of non-ramicolous fungi in 95G were higher than those in NG (Fig. 3).

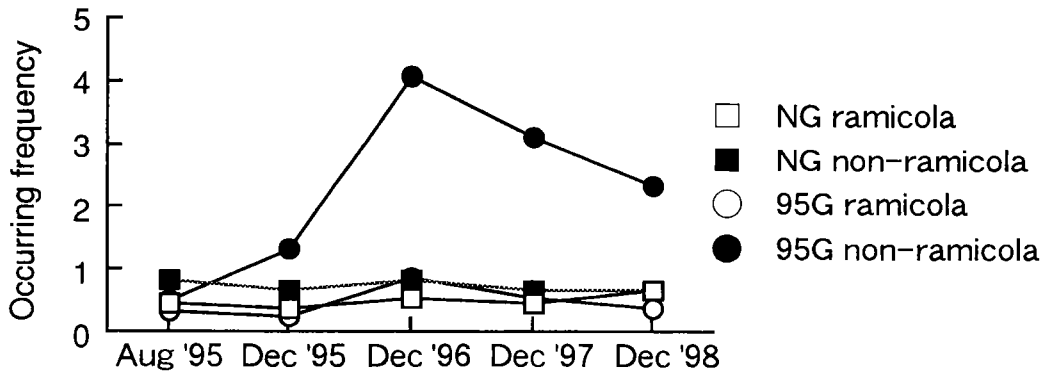

Fig. 3. Average occurring frequency of ramicola and non-ramicola fungi in the sub-plots of Plot 1

(5)Wood-foraging termites

Termites collected from wood litter bigger than 10 cm in diameter were seven and six species in natural and regenerate plots, respectively (Fig. 4). The predominant species was a fungus-growing termite *Macrotermes malaccensis* in both plots (Fig. 4). The percentage of *M. malaccensis* in all termite collections was lower in the natural plot than in the regenerate one, thus indicating that the species diversity was higher in natural forest than in regenerate one.

Termites collected from wood litter smaller than 10 cm in diameter were 11 and nine species in natural and regenerate plots, respectively. In both forests, *M. malaccensis* was collected from these small wood litter as from bigger ones. Some termites such as *Microtermes pakistanicus* and *Procapritermes angustignathus* were collected in both forests, which seemed to be unique to small wood litter since they were not collected from big wood litter at all.

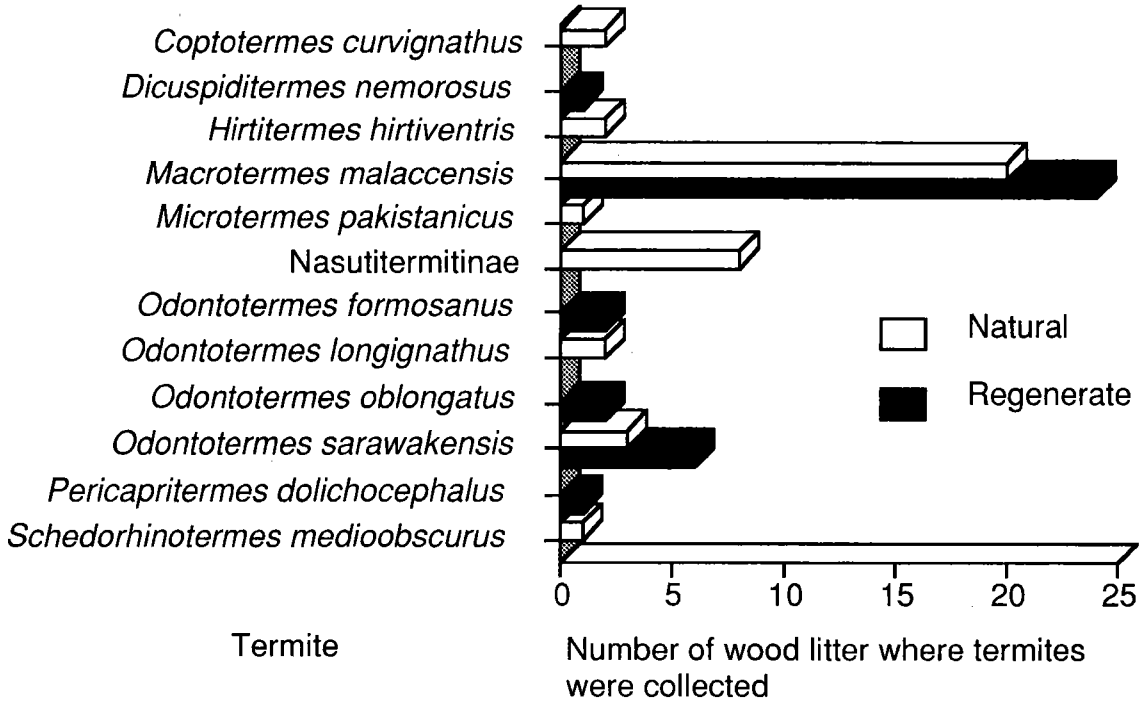

Fig. 4. Termites collected from wood litter in natural and regenerate forests

(6)Processional termites

The number of nests of processional termites were 20 and 12 in natural and regenerate plots, respectively. Activity level measured as the number of processions per day was higher in the natural plot than in the regenerate one in the first year of the study period, but became similar later in the second year.

Trees as foraging site showed peak abundance at < 30 cm and 50-70 cm in diameter at breast height (dbh) in the natural plot, but all trees (> 10 cm in dbh) in the natural plot were the most abundant in the dbh class of <20 cm (Fig. 5). Therefore, *Hospitalitermes* termites preferred large trees as foraging site. Large trees were more abundant in the natural plot than in the regenerate one. That may be the reason why *Hospitalitermes* was more abundant in natural forest.

(7)Tree growth in termite exclusion

Seedlings of *S. macroptera* did not grow well in either of termite-free and control enclosures. The maximum percentage of growth was 21%, but most seedlings stayed nearly at the same stature. Over 90% of seedlings died in two years of the growth experiment. They were planted only to the depth of 10 cm, therefore they may have suffered draught stress, especially in the period of haze in 1997.

5. Discussion

In regenerate forest, the number of wood litter, especially that of huge ones was much smaller than in natural forest. It may explain the fact that the occurrence of ramicolous fungi in regenerate forest was similar in natural forest, but the occurrence of non-ramicolous fungi was less frequent in regenerate forest than in natural one.

In natural forest, the number of non-ramicolous fungi increases after massive tree falls. The higher diversity of wood decay fungi in natural forest is probably because massive tree falls are more frequent there. It suggests that massive tree falls is one of the reasons of high diversity of wood decay fungi in natural forest. Intensive logging may reduce the number of fallen trees in the future, and cause reduction in diversity of wood decay fungi.

In the same way, logging disturbance may make the termite fauna poor by decreasing the abundance of foraging places as wood litter and standing trees. Wood litter is one of the

major source of nutrients once utilized by forest trees. As wood decay fungi and termites decompose it and release nutrients to the environment, recycling of nutrients proceeds through intake of them by trees. Simultaneously, wood residues are incorporated in soil, thus contributing to create soil structure. Termites also contribute to soil structuring by excavating tunnels in soil and transporting soil to construction of tunnels and nests. We have to create a moderate and sustainable way of logging and regeneration by regarding the decomposer organisms as one of the indispensable factors in the process.

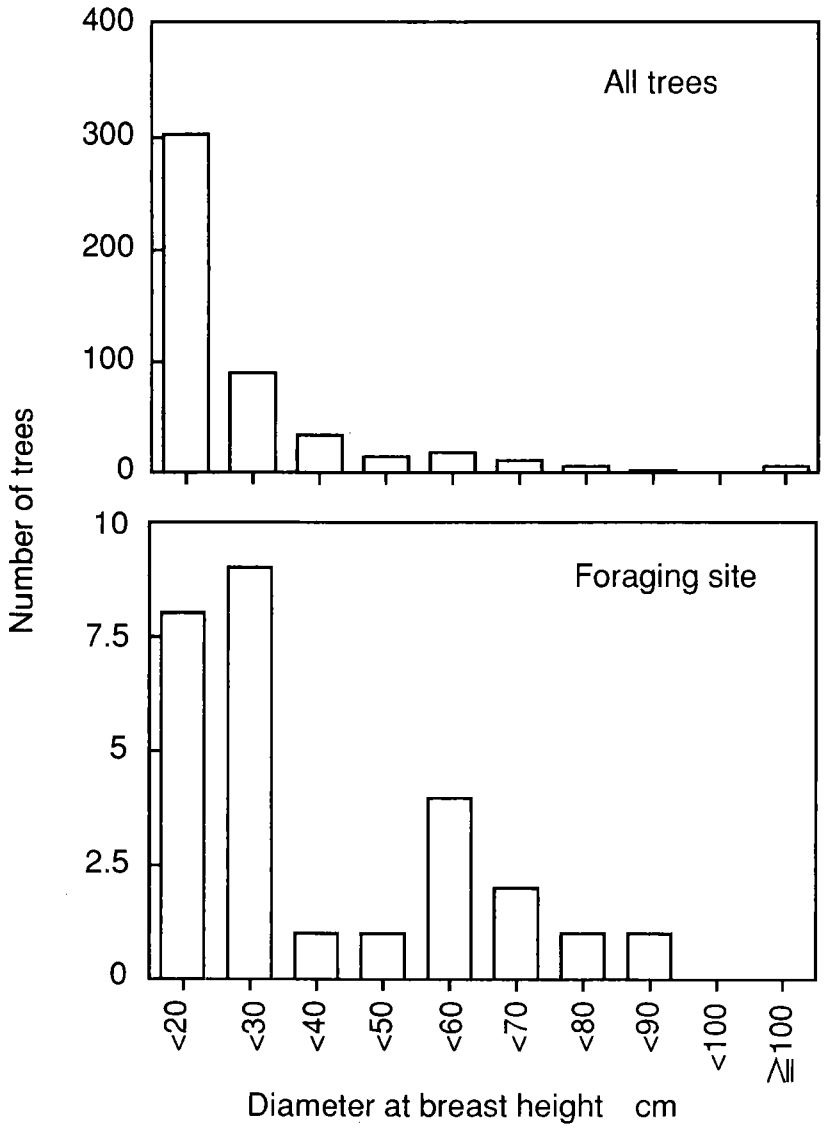

Fig. 5. Frequency distributions of all trees and trees as foraging site of *Hospitalitermes* termites in the natural forest plot