# The Influence of Selective Logging to Decomposition of Leaf Litter in Tropical Forest

**Motohiro Hasegawa[1], Masamichi T. Ito[2], Tatsuya Kawaguchi[2]**
[1] *Kiso Experimental Station, Forestry and Forest Products Research Institute*
[2] *Yokohama National University*

## Introduction

Lavelle (1997) suggested that the role of soil fauna in ecosystems could be divided into three groups, i.e. ecosystem engineer, litter transformer and microbial food web. Litter transformer and ecosystem engineer enhanced litter decomposition processes through their feeding activities (Yamashita and Takeda 1998) and thus have an important ecosystem function. Forest management may affect biological assemblage of decomposers, which may feed back to decomposition rate. However, the influence of forest management on their function in tropical forests has not fully been reported. In our study, the influence of selective logging on the decomposition of leaf litter in tropical forest was investigated and discussed in relation to soil animal activity.

It has been widely recognized that forest disturbance can affect nutrient cycling (Siira-Pietikäinen et al. 2001; Palviainen et al. 2004) and soil biota (Seastedt and Crossley 1981; Holloway et al. 1992; Siira-Pietikäinen et al. 2003; Negrete-Yankelevich et al. 2007).

Selective harvesting or setting logging roads/skid trails in tropical forest might influence the decomposition processes, because they cause the changes of plant community (Burghouts et al. 1994) and climatic conditions (Siira-Pietikäinen et al. 2001), which lead to the changes of soil microbial or faunal components (Davies et al. 1999). Changes in the relative abundance of some groups of soil and litter invertebrates due to selective logging have been reported (Eggleton et al. 1995; Lima et al. 2000).

Recent studies have demonstrated that the soil fauna (mainly soil microarthropods) have a more profound effect on decay rate in wet tropical forests than in dry tropical, temperate and sub-alpine forests (Heneghan et al. 1998; González and Seastedt 2000). Soil macro-fauna (ex. termite, Isopoda and millipedes) contribute to the disappearance of leaf litter by their feeding activities, and their activity results in the loss of leaf area during decomposition. In contrast, during the early stage of leaf-litter decomposition by microorganisms, leaf area does not significantly decrease but the weight of the litter decreases. Thus, it may be possible to evaluate the contribution of soil fauna (especially termites) by measuring the loss of leaf area in comparison to the loss of weight in the initial stage of litter decomposition.

The objective of the study is to investigate the influence of selective logging and skid trail to the decomposition process of tropical tree leaves, and to evaluate the contribution of soil fauna through the analysis of leaf-area loss during decomposition.

## Material and Methods

Our study was conducted in the Deramakot Forest Commercial Forest Reserve, Sabah, Malaysia. The details of the forest are shown in Chapters 2 and 3. We set two quadrates (2 X 2m) at the conventionally-logging forest (Tangkulap), the reduced-impact logging forest and the primary forest in Deramakot forest reserve. At each forest, one quadrate was placed at the edge of a skid trail (the width of the trail was 2.5 to 4m), and one quadrate was placed inside the forest (20m from the edge of the trail).

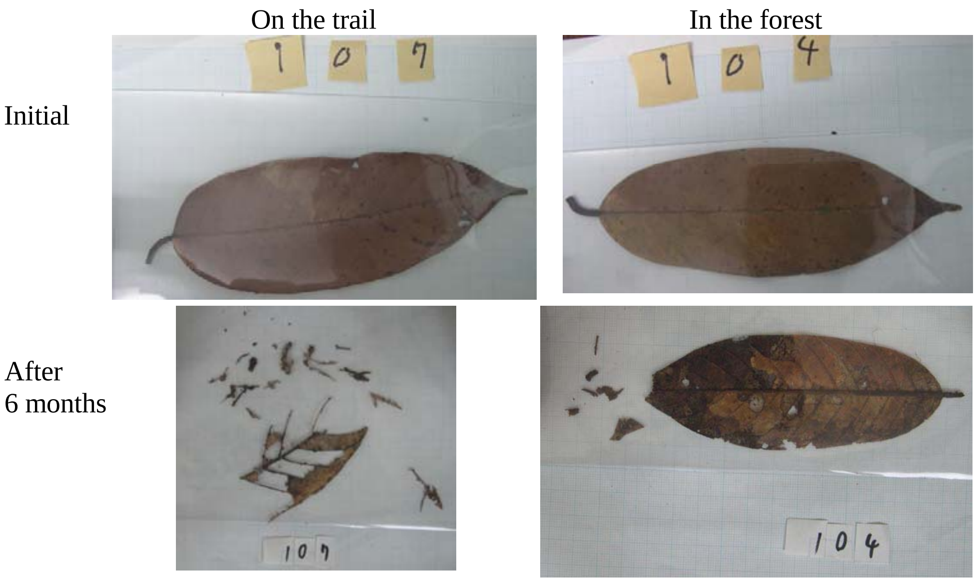


**Fig.1** Example of digital photo for leaf area estimation in *Shorea macroptera*

Fresh fallen leaves of *Shorea macroptera* and *Macaranga* sp. were collected from one tree of each species in March 2006. The litter was air-dried and the weight and area of each leaf were measured before placing them into litterbags. The leaf area was analyzed by Image J v. 1.37 (Rasband 2007) using digital image of the leaf. From the 2nd to the 4th March, 2006, we set 10 litterbags of *Shorea macroptera* and *Macaranga* sp. at each quadrate. Litterbags (20 x 20cm) were made of nylon net with a diamond shape mesh (long diagonal line: 4mm, short diagonal line: 2mm). Each litterbag included one piece of leaf for each tree species. On the 30th September, 2006, we collected all of the litterbags. The leaves recovered from the litterbags were measured for wet and air-dried weight as well as leaf area (cf. Fig. 1).

Weight and area remaining were analyzed using two-way analysis of variance (ANOVA) using SYSTAT10.2 (SYSTAT Software Inc., Richmond). The factors were forest type [primary forest (PR), reduced-impact logged forest (RIL) and conventionally-logged forest (CV)] and quadrate placement on the trail (out) and in the forest (in). Data were arcsine transformed before the analysis.

## Results

After the 6-month incubation in the field, the percentage of remaining weight relative to the initial weight for *Shorea macroptera* leaf litter ranged from about 16 to 39 %. The percentage of the litter weight in the primary forest was significantly larger than in conventional logging forest and RIL forest (Fig. 2, Table 1). Percentage of remaining weight for Shorea litter was significantly higher within forest than on trail (Fig. 2, Table 1). Significant interaction of two factors was not found (Table1). Percentage of remaining area relative to the initial area for Shorea litter ranged from 33 to 98 %, and it was significantly larger in the primary forest than in the conventionally-logging forest (Fig. 2, Table 1). Percentage of remaining area for Shorea litter was significantly larger within forest than on trail (Fig. 2, Table 1). Significant interaction of two factors was found;

RIL and CV on the trails showed lower percentage of leaf area compared to the other sites (Table1).

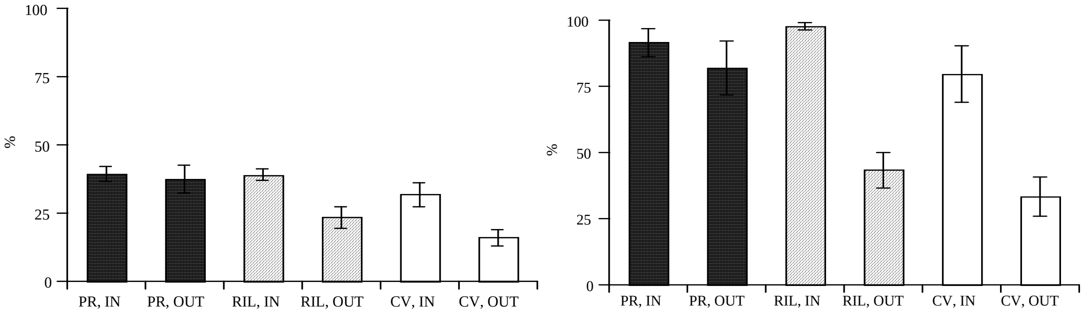


**Fig.2** The percentage of remaining weight (left) and area (right) for *Shorea macroptera* leaf litter
PR: Primary forest, RIL: Reduced-impact forest, CV: conventionally-logged forest, IN: within forest, OUT: on the trail. Bars indicate standard errors.

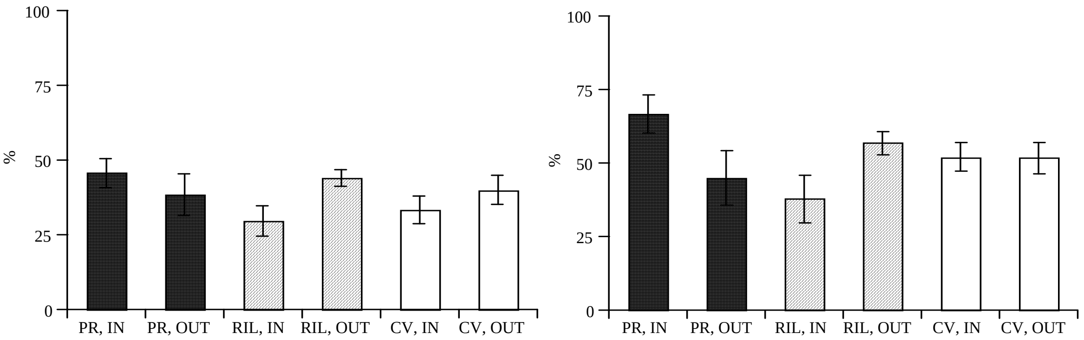


**Fig.3** The percentage of remaining weight (left) and area (right) for *Macaranga* sp. leaf litter
Legend as in Fig.2.

**Table 1** Results of two-way ANOVA for the effects of forest type and quadrate placement on the weight remaining and leaf area remaining of *Shorea macroptera* litter.

| | | *Shorea macroptera* | |
|---|---|---|---|
| | | Weight remaining | Area remaining |
| Forest type | *F* | 7.65 | 9.45 |
| | *P* | 0.001 | <0.001 |
| Placement | *F* | 13.11 | 41.18 |
| | *P* | 0.001 | <0.001 |
| Forest type X Placement interaction | *F* | 2.14 | 6.76 |
| | *P* | 0.100 | 0.002 |

**Table 2** Results of two-way ANOVA for the effects of forest type and quadrate placement on the weight remaining and leaf area remaining of *Macaranga* sp. litter.

| | | *Macaranga* sp. | |
|---|---|---|---|
| | | Weight remaining | Area remaining |
| Forest type | *F* | 0.83 | 1.20 |
| | *P* | 0.444 | 0.310 |
| Placement | *F* | 1.18 | 0.12 |
| | *P* | 0.282 | 0.732 |
| Forest type X Placement interaction | *F* | 2.14 | 4.78 |
| | *P* | 0.128 | 0.012 |

The percentage of remaining weight for Macaranga sp. ranged from 30 to 46 %(Fig. 3). No significant difference was found in the weight remaining of two factors and their interaction (Table2). The percentage of remaining area for Macaranga sp. was from 38 to 67 % (Fig. 3). Significant difference in the two factors was not found. However, significant interaction of the two factors was found; the litter placed within the PR forest showed a higher percentage of leaf area than that within the RIL forest (Table2).

## Discussion

The percentage of remaining weight after 6months ranged from 16 to 46%. These values are comparable to the previous studies of leaf litter decomposition in tropical forests (Anderson et al. 1983; Yamashita and Takeda 1998; Sundarapandian and Swamy 1999). We expected that the litter of the pioneer species *Macaranga* sp. would decompose faster than that of *Shorea macroptera* because of the physical and chemical characters of *Macaranga* litter (softer texture and higher nutrient concentration). However, the decomposition rate was approximately the same in this study.

On the trail, soil-water content is often lower than in the forest, which likely limits the activity of soil microorganisms. However, the weight loss of *Shorea* leaves was greater on the trail of RIL and CV. The greater weight loss on the trail of RIL and CV was accompanied by the greater rate of the disappearance of leaf area. Activities of soil macrofauna in the litter decomposition involve the loss of weight and area of litter. Therefore, the difference in remaining leaf area may be attributable to macro-faunal feeding activity. The difference in the loss of weight and area between within-forest and trail was more prominent in *Shorea* leaves than in *Macaranga* leaves. Animal feeding habit might have contributed to the different pattern of decomposition between tree species.

In tropical forests, termites are an important faunal component for litter decomposition (Abe and Matsumoto 1979; Petersen and Luxton 1982). Yamashita and Takeda (1998) suggested that the soil animals especially termites accelerated leaf litter decomposition by their feeding in Malaysian tropical forests. Lima et al. (2000) suggested that disturbances such as logging which reduces the abundance of some species of termites could reduce the rate of litter breakdown inside a forest.

In our study area, however, the density of termites was not so high, compared with other sites in tropical area (Abe and Matsumoto 1979; Eggleton et al. 1999; Hasegawa et al. 2006). Burghouts et al. (1992) also suggested that the termite density in Danum Valley in Sabah was smaller than that in the other sites in Asia and Africa.  In Borneo, Eggleton et al. (1999) suggested that selective logging appeared to have relatively little effect on termite assemblages, although soil-feeding termites may be moderately affected by this level of' disturbance. In the same study area as our current study, Hasegawa et al. (2006) suggested that the density of termites in the PR site was higher than that in the CV. Thus, the contribution of termites to the difference in decomposition between the PR and CV sites might be less important. However, termite distribution is generally heterogeneous, and they can bring litter to their nests, that might have not been located in our sampling zone. Thus, we might have missed the activity of termites in the CV site. In addition, we did not identify the species of termites. Some important groups of termites (ex. *Macrotermes*) may be included in the CV sites. In contrast, Hasegawa et al. (2006) suggested that isopoda and diplopoda density was higher in the CV sites. Tsukamoto and Sabang (2005) suggested that earthworm and isopods increased in *Acacia* plantation than in mixed Dipterocarps forest. Hassall et al. (2006) also suggested that the relative abundance of individual species of Isopoda was highest in the most disturbed environment. Further ecological study of termites and Isopoda are needed.

In conclusion, conventional logging and the creation of skid trails in this study area might accelerate the decomposition process. Greater litter fragmentation may enhance surface runoff of fragmented litter upon rainfall events. The enhanced runoff may aggravate the condition for the colonization of other soil biota and tree seedling, and may lead to a successive loss of biodiversity in that area (Tsukamoto and Sabang 2005; Ruan et al. 2005).

## References


Abe T, and Matsumoto T (1979) Studies on the distribution and ecological role of termites in a lowland rain forest of west Malaysia (3) Distribution and abundance of termites in Pasoh forest reserve. Jap J Ecol **29**:337-351

Anderson J M, Proctor J, Vallack H W (1983) Ecolological studies in four contrasting lowland rain forests in Gunung Mulu national Park, Sarawak. Journal of Ecology **71**:503-527

Burghouts T, Ernsting G, Korthalis G, De Vries T (1992) Litterfall, leaf litter decomposition and litter invertebrates in primary and selectively logged dipterocarp forest in Sabah, Malaysia. Phil. Trans. R. Soc. Lond. B **335**:407-416

Burghouts T B A, Campbell E J F, Kolderman P. J. (1994) Effects of Tree Species Heterogeneity on Leaf Fall in Primary and Logged Dipterocarp Forest in the Ulu Segama Forest Reserve, Sabah, Malaysia. J Trop Ecol **10**:1-26

Davies R G, Eggleton P, Dibog L, Lawton H, Bignell D E, Brauman A, Hartmann C, Nunes L, Holt J, Rouland C (1999) Successional response of a tropical forest termite assemblage to experimental habitat perturbation. J Appl Ecol **36**:946-962

Eggleton P, Bignell D E, Sands W A, Waite B, Wood T G, Lawton J H (1995) The Species Richness of Termites (Isoptera) Under Differing Levels of Forest Disturbance in the Mbalmayo Forest Reserve, Southern Cameroon. J Trop Ecol **11**:85-98

Eggleton P, Homathevi R, Jones D T, MacDonald J A, Jeeva D, Bignell D E, Davies R G, Maryati M (1999) Termite assamblages, forest disturbance and greenhouse gas fluxes in Sabah, East Malaysia. Phil Trans R Soc Lond B **354**:1791-1802

González G, Seastedt T R (2000) Comparison of the abundance and composition of litter fauna in tropical and sub-alpine forests. Pedobiologia **44**:545-555

Hasegawa M, Ito M T, Kitayama K, Seino T, Chung A Y C (2006) Logging effects on soil macrofauna in rain forests of Deramakot Forest Reserve, Sabah, Malaysia. The second Workshops on synergy between carbon management and biodiversity conservation in tropical rain forests, Workshop proceedings:53-60

Hassall M, Jones D, Taiti S, Latipi Z, Sutton S L, Mohammed M (2006) Biodiversity and abundance of terrestrial isopods along a gradient of disturbance in Sabah, East Malaysia. Eur J Soil Biol 42 (2006) **42,** supplement:197–207

Heneghan L, Coleman D C, Zou X, Crossley Jr. D A, Haines B L (1998) Soil microarthopod community structure and litter decomposition dynamics: A study of tropical and temperate sites. Appl Soil Ecol **9**:33-38

Holloway J D, Kirk-Spriggs A H, Khen C V (1992) The Response of Some Rain Forest Insect Groups to Logging and Conversion to Plantation. Phil Trans R Soc Lond B **335**:425-436

Lavelle, P (1997) Faunal activities and soil processes: Adaptive strategies that determine ecosystem function. Advances in Ecological Research **27**:91-132.

Lima A P, Cordeiro-Duarte A C, Luizao F J, Higuchi N (2000) Effect of selective logging intensity on two termite species of the genus Syntermes in Central Amazonia. For Ecol Manag **137**:151-154

Negrete-Yankelevich S, Fragoso C, Newton A C, Heal O W (2007) Successional changes in soil, litter and macroinvertebrate parameters following selective logging in a Mexican Cloud Forest. Appl Soil Ecol **35**:340-355

Palviainen M, Finer L, Kurka A M, Mannerkoski H, Piirainen S, Starr M (2004) Decomposition and nutrient release from logging residues after clear-cutting of mixed boreal forest. Plant and Soil **263**:53-67

Petersen H, Luxton M (1982) A comparative analysis of soil fauna populations and their role in decomposition processes. Oikos **39**:288-388

Rasband W S (2007) ImageJ, V. 1.37 U. S. National Institutes of Health, Bethesda, Maryland, USA, http://rsb.info.nih.gov/ij/.

Ruan, H., Y. Li, and X. Zou. 2005. Soil communities and plant litter decomposition as influenced by forest debris: Variation across tropical riparian and upland sites. Pedobiologia **49** 529—538.

Seastedt T R, Crossley Jr D A (1981) Microarthropod response following cable logging and clear-cuting in the Southern Apparachians. Ecology **62**:126-135

Siira-Pietikäinen A, Haimi J, Siitonen J (2003) Short-term responses of soil macroarthropod community to clear felling and alternative forest regeneration methods. For Ecol Manag **172**:339–353

Siira-Pietikainen A, Pietikainen J, Fritze H, Haimi J. (2001) Short term responses of soil decomposer communities to forest management: clear felling versus alternative forest harvesting methods. Can J For Res **31**:88-99

Sundarapandian S M, Swamy P S (1999) Litter production and leaf-litter decomposition of selected tree species in tropical forests at Kodayar in the Western Ghats, India. For Ecol Manag **123** 231-244

Tsukamoto J, Sabang J (2005) Soil macro-fauna in an *Acacia mangium* plantationin comparison to that in a primary mixed dipterocarp forest in the lowlands of Sarawak, Malaysia. Pedobiologia **19**:69-80

Yamashita T, Takeda H (1998) Decomposition and nutrient dynamics of leaf litter in litter bags of two mesh sizes set in two dipterocarp forest sites in Penisular Malaysia. Pedobiologia **42**:11-21