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Spatial distribution of abundant tree species at a mixed dipterocarps forest in Bukit Bangkirai, East Kalimantan three years after long drought and forest fire

Distribusi spasial jenis pohon melimpah pada hutan Dipterokarpa campuran di Bukit Bangkirai, Kalimantan Timur tiga tahun setelah kekeringan yang panjang dan kebakaran hutan

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Abstract. Siregar M. 2017. *Spatial distribution of abundant tree species at a mixed dipterocarps forest in Bukit Bangkirai, East Kalimantan, three years after long drought and forest fire. Pros. Sem Nas Masy Biodiv Indon 3: 246-251.* This study aims to determine the distribution of abundant tree species that survive or grow three years after long drought and forest fires. The tree distribution data were extracted from the database of three permanent plots at Bukit Bangkirai, namely: 1.0 ha plot at heavily damaged forest due to forest fires (HD-plot), 0.3 ha at lightly damaged forest due to forest fires (LD-plot) and 1.0 ha plot in a natural unburnt forest (K-plot). The distribution pattern was analyzed by using Morisita's indices of dispersion and Jaccard's indices of species association. Correlation of tree density with height and slope of land were also analyzed in each plot.The results showed that the most of the abundant tree species were clumped at small scales, and the clumps were randomly distributed (inter-clump distribution is random). An exception was found for *Macaranga glaberrimus* at K-plot and *Madhuca kingiana* at LD-plot which have random distribution both on small and large plots. Individuals of *M. kingiana* in K-plot were clumped at larger scales, and they were distributed uniformly within the clumps (intra-clump distribution is uniform), which were distributed in the valley and steep slope. Inversely, *Shorea laevis* is rarely found in valleys and steep slopes. In HD-plot, distributions of *Macaranga gigantea, Homalanthus populneus* and *Mallotus paniculatus* were concentrated in the valley and in the lower parts of the slopes which have water availability. It can be concluded that the distribution of secondary species in HD-plot is much influenced by water availability, whereas in LD-plot and K-plot more affected by light availability.

Keywords: Abundant species, Bukit Bangkirai, East Kalimantan, forest fire, spatial distribution

Abstract. *Siregar M. 2017. Distribusi spasial jenis pohon melimpah pada hutan Dipterokarpa campuran di Bukit Bangkirai, Kalimantan Timur tiga tahun setelah kekeringan yang panjang dan kebakaran hutan. Pros. Sem Nas Masy Biodiv Indon 3: 246-251.* Penelitian ini bertujuan untuk mengetahui distribusi jenis-jenis pohon melimpah yang bertahan atau tumbuh tiga tahun setelah mengalami kekeringan dan kebakaran hutan. Data distribusi pohon disarikan dari database tiga petak permanen di Bukit Bangkirai, yaitu: petak hutan terbakar berat (HD-plot) dan terbakar ringan (LD-plot) yang disebabkan oleh kebakaran,serta hutan tidak terbakar (K-plot). Pola distribusi dianalisis menggunakan indeks persebaran Morisita dan indeks asosiasi jenis Jaccard. Dianalisis juga korelasi kepadatan pohon dengan tinggi dan kemiringan lahan di masing-masing petak. Hasilnya menunjukkan bahwa sebagian besar jenis pohon melimpah membentuk kelompok-kelompok kecil yang tersebar secara acak. Pengecualian ditemukan pada individu *Macaranga glaberrimus* di K-plot dan *Madhuca kingianadi* LD-plot yang tersebar acak baik pada unit petak kecil maupun besar. Individu *M. kingiana* di K-plot menyatu pada kelompok yang lebih besar terutama di bagian lembah dengan kelerengan curam, sebaliknya *Shorea laevis* jarang ditemukan di bagian lembah dan lereng curam. Pada HD-plot, distribusi *Macaranga gigantea, Homalanthus populneus* dan *Mallotus paniculatus* terkonsentrasi di lembah dan di bagian bawah lereng yang memiliki ketersediaan air. Dapat disimpulkan bahwa distribusi jenis-jenis pohon sekunder di HD-plot banyak dipengaruhi oleh ketersediaan air, sedangkan pada LD-plot dan K-plot lebih banyak dipengaruhi oleh ketersediaan cahaya.

Kata kunci: Bukit Bangkirai, distribusi spasial, East Kalimantan, jenis melimpah, kebakaran hutan

INTRODUCTION

In February-March 2001 established three permanent plots at Bukit Bangkirai, East Kalimantan, a cooperative research project between Research Center for Biology, Indonesian Institute of Sciences (RCB-LIPI), Bogor, Indonesia and National Institute for Environmental Studies (NIES), Tsukuba, Japan. The theme of the project is Impacts of Forest Fires on the Natural Resources and Evaluation of Restoration of Ecosystems after Forest Fires. This project was financially supported by the Global Environment Research Fund of Ministry of the

Environment, Japan (see Simbolon et al. 2005).

Two plots were established at disturbed forest due to the long drought in 1997-1998 and wildfires in early 1998, and another at a forest without fire. At heavily damaged forest almost all tree plants were dead due to forest fires and only some trees grown at the river sides remained alive, while at the lightly damaged forest some trees that might be resistant to forest fire were still alive. Three years after fires, the forest floor was covered by ferns, herbs and small trees of pioneer species.

Several results of studies of permanent plots Bangkirai has been widely published i.e. soil microbial (Rahmansyah and Sudiana 2004; Nurkanto 2007); reestablishment of rattans (Watanabe et al. 2009); diversity of epiphytes and lianas (Simbolon 2007); diversity of Bryophytes (Windadri et al. 2010) and potential soil water repellency (Kajiura et al. 2012). However, local distribution of abundant tree species in the three permanent plots has not been widely discussed. This paper intends to analyze in more details the spatial distribution of abundant tree species in 3 permanent plots at Bukit Bangkirai three years after fire. What are the factors that affect the distribution of these trees in heavily and lightly damaged forests after forest fires?The results are important in understanding the succession process of the forest after fire.

MATERIALS AND METHODS

Study area

The study sites was located in three permanent plots in Bukit Bangkirai, East Kalimantan, i.e 1.0 ha plot (100mx100m) at heavily damaged forest due to forest fires (HD-plot), 0.3 ha (50mx60m) at lightly damaged forest due to forest fires (LD-plot) and 1.0 ha plot (100mx100m) in a natural unburnt forest (K-plot) (see Simbolon et al. 2005). The site is a part of Mentawir and Batuampar hills at 110 m in altitude, located about 50 km in the northwest of Balikpapan City, East Kalimantan, managed as Nature Recreation Park by PT INHUTANI-1 (Figure 1).

Topographical condition of plots

At the plots established by Simbolon et al. (2005), relative elevations were measured at the corner points of 10 x 10 m subplots by using a compass. The values were then figured in a three-dimensional graph to perform the topographic condition of each plot (Figure 2). Axis X (1-5-10) of the three plots is running from east to west. Highest corner points at each sub-plot of K, LD and HD-plot were D10, X0 and E6, while the lowest points were I0, F4, and H-1, respectively. The differences in the ground height between the highest and lowest corner points were 33, 16.3 and 19.7 m in K-plot, LD-plot and HD-plot, respectively.

Data analysis

Three of abundant tree species (dbh ≥ 5cm) in each plot was extracted from a data base of the permanent plot (see also Simbolon et al. 2005). Three of abundant species in K-plot were *Shorea laevis* Ridl (114 trees/ha), *Madhuca kingiana* (Brace.) H.J.L (65 trees/ha) and *Macaranga glaberrimus* (57 trees/ha), in LD-plot were *Macaranga gigantea* Muell-Arg. (117 trees/ha), *Madhuca kingiana* (Brace.) H.J.L. (100 tresses/ha)and *Durio acutifolius* (Mast.) Kost. (27 trees/ha), while in HD-plot were *Macaranga gigantea* Muell-Arg (173 trees/ha), *Homalanthus populneus* (Giesl.) Pox. (34 trees/ha) and *Mallotus paniculatus* (Lmk.) M.A (26 trees/ha).

Spatial distributions of abundant tree species in each plot were analyzed by using Morisita's indices of dispersion (Morisita 1959), while the association of species was calculated by using Jaccard's indices of species association (Mueller-Dombois and Ellenberg 1974). Correlation of tree density and ground height in each plot were calculated using MS Excel. Contour line refers to Simbolon et al. (2005). Each of abundant species in each of the plot is mapped based on the coordinates of each tree.

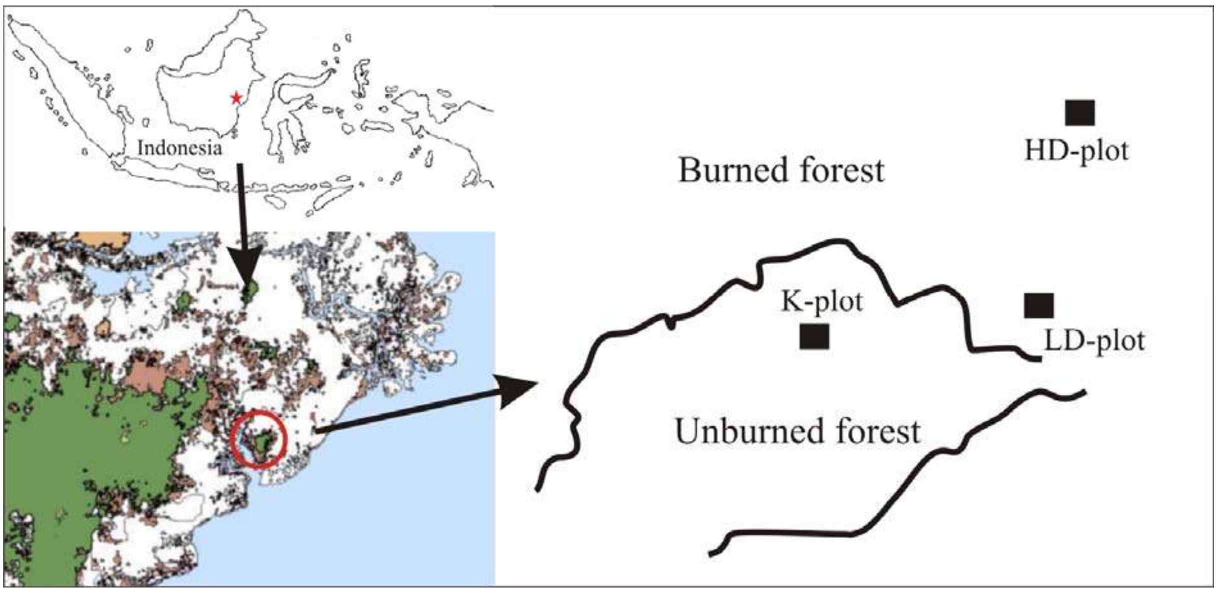

Figure 1. Location of permanent plot at Bukit Bangkirai, East Kalimantan, Indonesia (modified fromWatanabe et al. 2009)

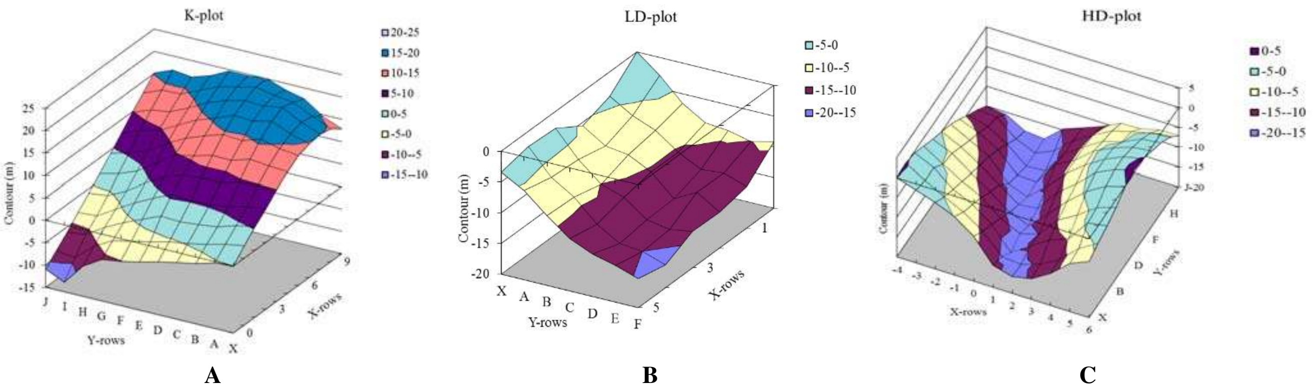

Figure 2. Topographical condition of the permanent plot. A. K-plot; B. LD-plot, C. HD-plot

RESULTS AND DISCUSSION

Result

Morisita index of dispersion (Morisita 1959) was applied to analyze the distribution pattern of abundant tree species, which might have an impact on the sub-plots grouping. The results showed that most of the abundant tree species were clumped at small scales, and the clumps were randomly distributed (*inter-clump distribution is random*) and dispersed randomly on the larger plot unit (Figure 3-5). An exception was found for*Macaranga glaberrimus* at K-plot and *Madhuca kingiana* at LD-plot which have random distribution both on small and large plots. Individuals of *M. kingiana* at K-plot were clumped at larger scales, and they were distributed uniformly within the clumps (*intra-clump distribution is uniform*).

Figure 6 shows the distributions of *Shorea laevis, Madhuca kingiana* and *Macaranga glaberrimus* within K-plot. When K-plot in Figure 6 was overlaid on K-plot in Figure 2, it was found that *S. laevis* were distributed almost over the entire sub-plots except in valley and the steep slope facing southeast. Similar to *M. glaberrimus*, but this species is still found in parts of the valley and the steep slope. The association index of both species (*S. laevis* and *M. glaberrimus*) was 27.8%. Inversely, individuals of *M. kingiana* were distributed in the valley and the steep slope facing southward. There is a positive correlation between ground height with tree density for *S. laevis* and *M. glaberrimus*, whereas for *M. kingiana* has a negative correlation, where it is more abundant in the valley (Figure 7). Association indices of *M. kingiana*-*S. laevis* and *M. kingiana*-*M. glaberrimus* were relatively small, 15.4 and 22.0 %, respectively.

The influence of ground height level on distributions of *Macaranga gigantea*, *M. kingiana* and *Durio acutifolius* in LD-plots were not very visible, given the levels of ground height are not represented (only -10 and -5) (Figure 6; 8). But, based on field observations, *M. gigantea* were distributed in gaps, while most of *M. kingiana* were under closed canopy. Index of association of both species was 29.2%. Generally, *D. acutifolius* was occupied of the upper canopy layer which receives more light.

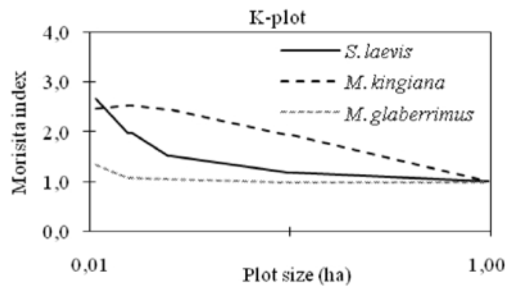

Figure 3. Values of Morisita's Index at different plot sizes for *Shorea laevis, Madhuca kingiana* and *Macaranga glaberrimus* in K-plot.

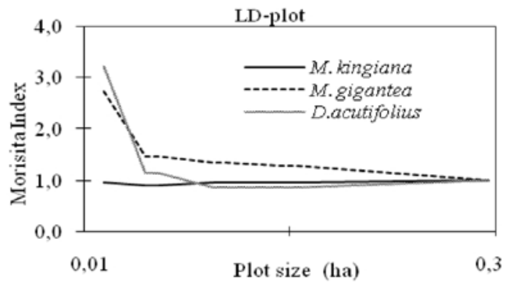

Figure 4. Values of Morisita's index at different plot sizes for *Madhuca kingiana*, *Macaranga gigantea* and *Durio acutifolius* in LD-plot.

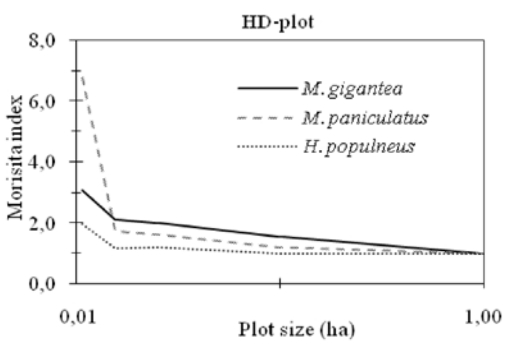

Figure 5. Values of Morisita's Index at different plot sizes for *Macaranga gigantea, Mallotus paniculatus* and *Homalanthus populneus* in HD-plot.

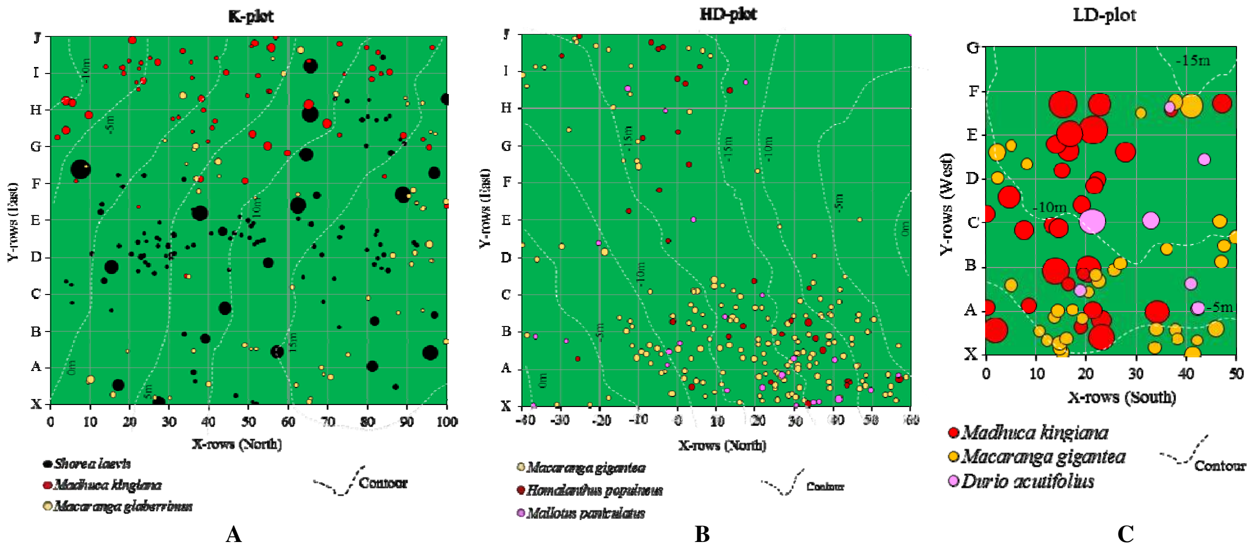

Figure 6. Distribution of three abundant tree species (dbh ≥ 5cm) in K-plot, LD-plot and HD-plot. The size of the dot is to describe the proportion of dbh of every tree in each plot, but not proportion to the plot. Contour line refers to Simbolon et al (2005)

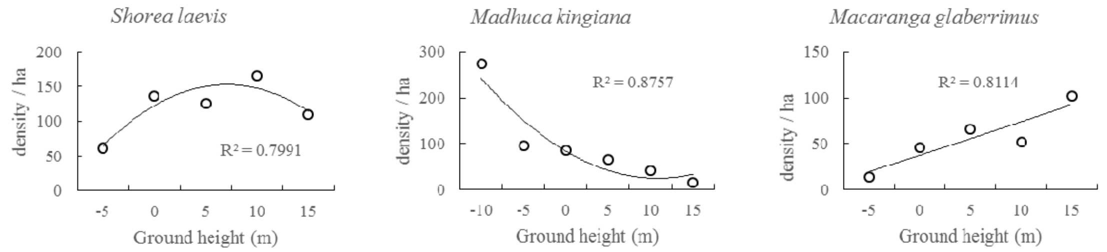

Figure 7. The correlation between ground height with density for *Shorea laevis, Madhuca kingiana* and *Macaranga glaberrimus* in K-plot

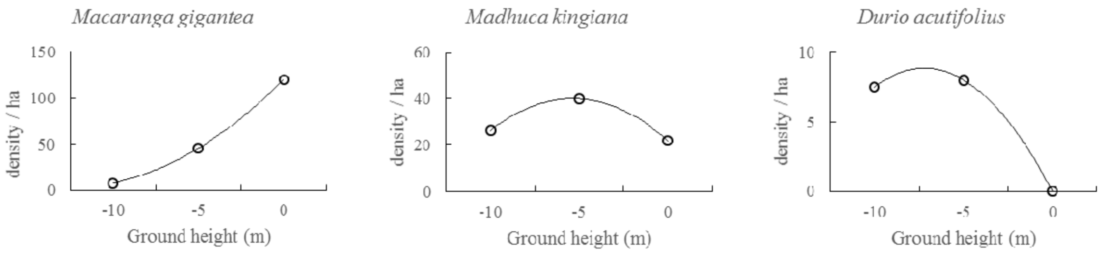

Figure 8. The correlation between ground height with density for *Macaranga gigantea, Madhuca kingiana* and *Durio acutifolius* in LD-plot

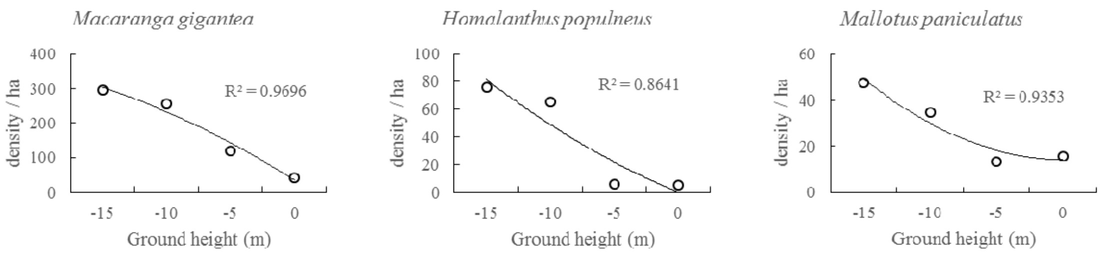

Figure 9. The correlation between ground height with density for *Macaranga gigantea, Homalanthus populneus* and *Mallotus paniculatus* in HD-plot

In HD-plot which were open due to heavy vegetation damage, distributions of *M. gigantea, Homalanthus populneus* and *Mallotus paniculatus* were concentrated in the valley and in the lower parts of the slopes (Figure 6; 9). These three species were light demanding species and recruited after the fires.

Discussion

Madhuca kingiana, Macaranga glaberrimus, Macaranga gigantea, Mallotus paniculatus and *Homalanthus populneus* were light demanding species and hence commonly found in the secondary forest and the gaps of primary forests where are happened increase in the duration and intensity of direct sunlight to lower strata of the forest (Denslow 1987). However, the tolerance of each species to the level of shade canopy is relatively different.

The depth of canopy layer seems to influence the distribution of *M. kingiana* as shown in the LD-plot. *M. kingiana* was found not only in the gaps, but mostly at the areas under the relatively bright canopy cover as the effect of decreasing density of trees and the upper layer canopy that are damaged after the forest fires.This is thought to be the reason why *M. kingiana* is randomly distributed in the LD-plot (Figure 4), whereas in K-plots that have a more closed canopy layer it tends to clump on the slope (Figure 3; 6). In this respect, the abundance of *M. kingiana* at the slopes of K-plot is not related to gaps. Gaps are when one or a few canopy trees die (or are injured) in a forest which causes the canopy to open (Yamamoto 2000). Whitmore (1984) reported that slope areas are mainly occupied by medium sized light-demanding tree species. Further, Halle et al. (1978) explained that this condition might relate to the canopy structure of trees in the slope and combination of gravitation effect and one-sided light penetration. It is important to note that the slope of K-plot is facing eastward so that the light penetration into the forest floor is sufficient for the growth of *M. kingiana*.

We recognize two kinds of trees, whose species are tolerant to shade, and which are intolerant or require much light (Swaine and Whitmore 1988). In this study, the most abundant trees in open or gap areas in LD-plot is *M. gigantea* known as light-demanding species (Asian Plant 2017). They are rarely found under closed canopy, thus forming clumped distribution pattern (Figure 4) in the gaps or open area which has more light penetration (Isa et al. 2015; Okuda et al. 2003). *D. acutifolius* also has the same distribution as *M. gigantea* (Figure 4) but has different habitats (Figure 6). This is reflected in association index for both species are the relatively small, which is 6.25%.*D. Acutifolius*is endemic to Borneo and listed asIUCN Red List of Threatened Species. This understorey tree occurs on poor sandy and clay-rich yellow soils, often in periodically inundated areas in lowland rainforest (World Conservation Monitoring Centre.1998).

The abundant tree species in HD plots that have a high degree of damage due to forest fires are *Macaranga gigantea, Homalanthus populneus* and *Mallotus paniculatus*. All three species are light-demanding. It seems that the need for light is not a limiting factor for the growth of the three species in the HD-plot, but it is thought to be the availability of water in the soil, where each species is different in sensitivity (Simbolon 2005). This is evident from the distribution of these three species in many valley areas (Figure 6). The relationship between soil height and tree density also strengthens this assumption (Figure 9).At the slope, the lower moisture content will increase water repellency potential, although it has a high soil organic matter (Kajiura et al. 2012). Mallik et al. (1984) reported that infiltration rate of water in the soil decreased by up to 74% and the rate of run-off increased in a burned forest comparing to those of a control site. Water stress might inhibit the growth of plants in hill slopes. Ponds in the valley areas may supply waters for the growth of plants in the valley and lower parts of the slopes, especially during the dry season. The escaped trees from the forest fires were also distributed more in the valley rather than in upper slopes.

Three years after heavy damage due to forest fires (HD-plot), secondary tree species such as *M. gigantea, M. paniculatus* and *H. populneus* was important species in constructing an early community of forests (Turner et al. 1997). They are found in the open areas with enough available water for growth. They are pioneer tree species in HD-plot.The most abundant species in LD-plot was *M. kingiana*, which were grown under the canopy of surviving trees after the forest fires, while gap areas were dominated by *M. gigantea*. Secondary species at the unburn forest (K-plot) was lower in density as a result of the dense canopy cover. The abundant species in this forest (K-plot) are climax species such as *S. laevis* whose density reaches 114 trees per hectare. This species was drastically decreased its population in LD-plot (13 trees ha^{-1}) and HD-plot (1 tree ha^{-1}) after the forest fire. Whether the population of the species in LD-plot and HD-plot was low before the forest fire or the species was sensitive to the fire is still uncertain, and further researches are still needed.

Thus it can be concluded that in the unburned forest (K-plot) or lightly damaged forest due to forest fires (LD-plot), light penetration becomes a very important factor in shaping the pattern of distribution of secondary species. Whereas in the heavily damaged forest due to forest fires (HD-plot), water availability becomes the determinant of its distribution. *M. kingiana* is a tolerant species at moderate shade when compared to *M. gigantea* who need full light for its growth.

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