



Species diversity of Gunung Merapi National Park, Java, Indonesia following 2006 eruption

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Abstract: Vegetation succession after a volcanic eruption is relatively a rare phenomenon, and the study on the subject matter is rather limited. A study was carried out at the Gunung Merapi National Park (GMNP) with the objectives of determining species diversity and distribution, two years after eruption. Five plots (P1, P2, P3, P4 and P5), each with the size of 50 x 20 m were established. The stand distribution pattern was calculated by use of agglomeration and dispersion index, and growth trend of dominant species was measured by correlation between density, diameter and height. The studies show that the importance value index (IVI) of most species was very low, with only the following species adaptive to the post-eruption environment of GMNP, namely *Acacia decurrens*, *Acacia villosa*, *Cincona rubecea*, *Erythrina hypaporus*, *Euophorbia ciacembus*, *Ficus kubeba*, *Psidium guajava*, *Palotus* sp, *Pinus merkusii*, *Schima wallichii* and *Trema* sp. The dominant species in the area are *A. decurrens* and *P. merkusii*. The distribution of pattern of *A. decurrens* can be categorized as clumpy, with the index of dispersion (IE) of >1.27 and $R \approx 0$, whereas *P. merkusii* is distributed in regular ($IE \approx 1.27$ and $R > 2.15$) and random patterns ($IE \approx 1.27$, $R < 2.15$). The relationship between density and diameter of *A. decurrens* are inversely proportional at P1, P2, P3 and P4). Similarly, the relationship between density and height of the species at P1, P2, P3 and P4 are inversely proportional.

Key words: Catastrophic eruption, Species distribution, *A. decurrens*, *P. merkusii*

Introduction

Over the years, Mount Merapi has recorded more than 61 chronological eruptions (VSI, 1990; Lavigne *et al.*, 2000), and in 2006, it has erupted simultaneously with the earthquake in Bantul district, Java, Indonesia. Merapi is a stratovolcano, and one of the most active volcanic mountains in the world (Purbawinata *et al.*, 1997; Lavigne *et al.*, 2000; Sutikno, 2002). During the period between the months of May to June 2006, Merapi has erupted three times (Charbonnier and Gertisser, 2008). The lava from the May, 2006 eruption was directed to Krasak and Bedok rivers, but the lava from the June eruption was directed to the Gendol river, which has resulted in disturbances in forest conservation and recreation.

Generally, natural succession will take place after any disturbance led by pioneer species (may be trees, shrubs and lianas), which require high-light environment for their establishment (Whitmore, 1983). Detailed information on succession, especially after volcanic eruption is very important for sound management and future references. Assessment of sere can be carried out by species diversity analysis, which provide fundamental information about the existing environment status (Gaston and Spicer, 2004), community type (Park *et al.*, 2003), and in the advanced condition of species diversity support the existing environment (Naeem and Baker, 2005; Kiessling, 2005). Based on this premise, a study was carried out in Mount Merapi National Park to assess the successional processes taken place after volcanic eruption, and with more specific objectives of elucidating species diversity, distribution pattern and dominance.

Materials and Methods

Study site: The study was carried out in Gunung Merapi National Park (GMNP), which is situated in the Sleman district, Yogyakarta, Indonesia (Fig. 1). GMNP which covers an area of about 6.410 ha, is located on elevation ranging from 600 to 2967 m asl (Purbawinata *et al.*, 1997). The climate of the area is categorized as wet tropic with the climate of C with Q 33.3-66% based on Schmidt and Fergusson classification. The annual rainfall of about 875 mm year⁻¹ to about 2527 mm year⁻¹, with the wet months of November to May, and the dry month of June to October (Sutikno, 2002).

A total of 5 phytosociological relevés or permanent sample plot (numbering as P1, P2, P3, P4 and P5), each with the size of 50 x 20 m were established on two distinct locations *i.e.*, P1 (at elevation of 1210 m above sea level) and P2 (1220 m) were placed on the west bank of Gendol river, whereas P3 (1250 m), P4 (1260 m) and P5 (1300 m) were placed on the east bank of the river. Each plot was divided into 25 quadrates (each the size of 2 x 2 m). According to Lavigne *et al.* (2000), the disturbance because of eruption can be categorized into two conditions *viz.*, the first condition was caused by the spinning clouds of super-heated gases and mud-stream (P1, P2, P3 and P4), and the second one was only caused by the spinning clouds of super-heated gases (P5).

All species in the plots were identified to the species level. In addition, total height, diameter at breast height (DBH) and distribution of individual tree in each quadrate (*i.e.* positioning of individual tree along the x and y coordinates) were also recorded. Species diversity among the plots was analyzed via ANOVA and

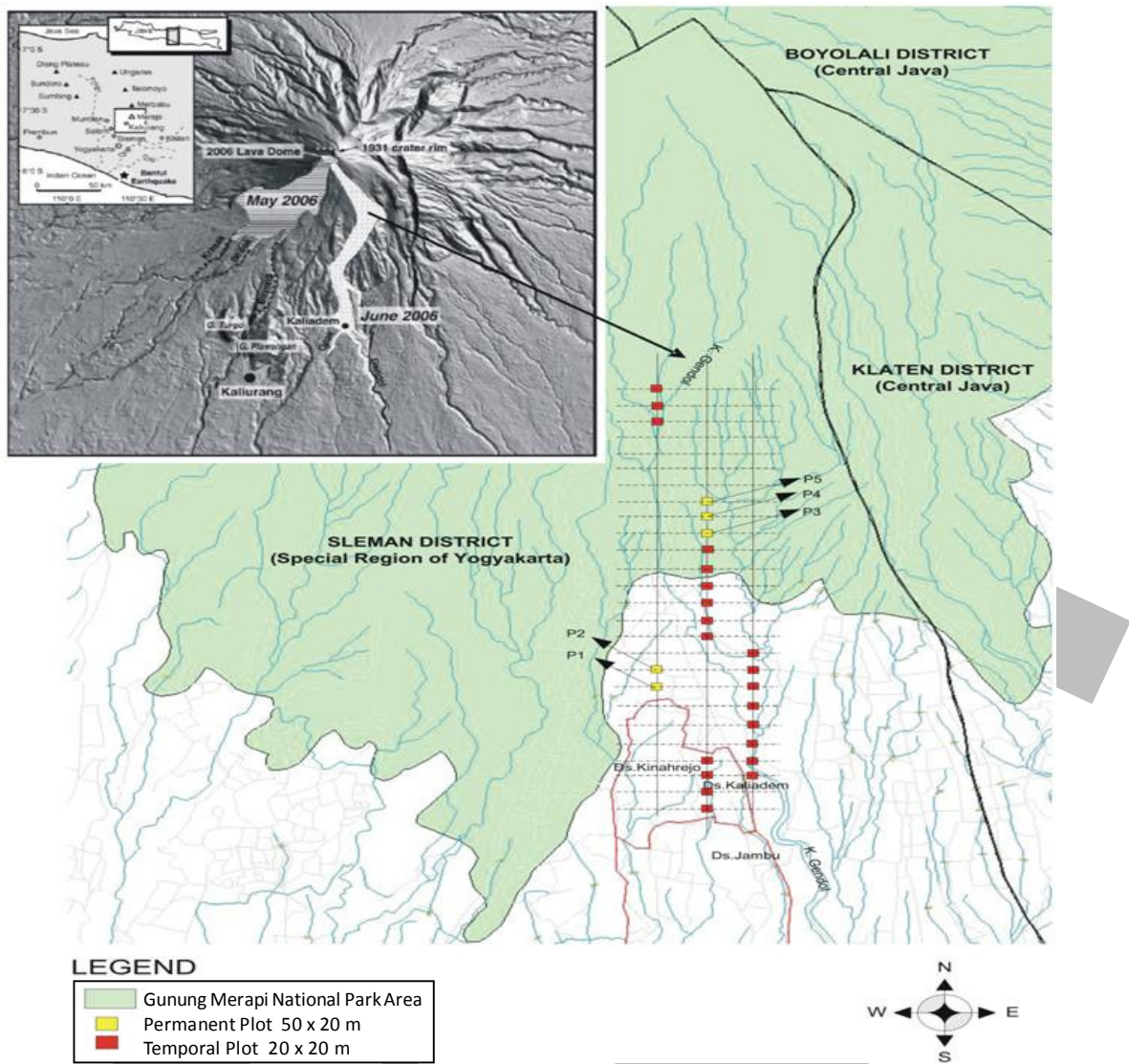


Fig. 1: Gunung Merapi National Park, Java, Indonesia (Modified from Charbonnier and Gertisser, 2008)

DMRT using the following parameters, namely species richness, heterogeneity and evenness (Krebs, 1989). Species richness was calculated by use of Jacknife estimate method (Helteshe and Forrester, 1983), whereas heterogeneity was calculated by the Shannon Wiener method. In addition, the spatial distribution of the species was fixed by the agglomeration index (Krebs, 1989), and the index dispersion was calculated by the Ebehardt method (Hines and Hines, 1979). The last parameter observed in this study is the species overall growth, and its correlation to stand density.

Results

Species richness after two years of post-eruption showed significant differences between the study plots, with P1 recorded the lowest richness level (1.907), and the highest species richness was exhibited by P5 (Table 1).

The table also shows that the heterogeneity value followed similar trend with the richness value, where P5 exhibited the highest

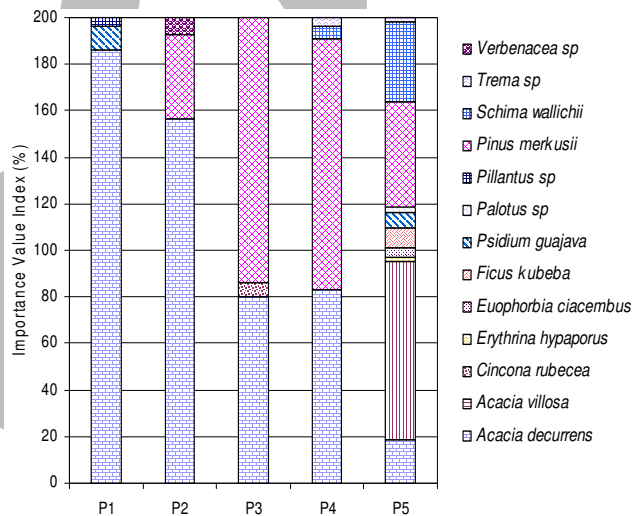


Fig. 2: Species importance value index

value, while P1 had the lowest value. This heterogeneity showed that species distribution at P5 was the highest compared than the other plots. In addition, the plot also attained the highest evenness value, and once again the lowest value was displayed by P1. On the other hand, in term of individual species density, P1 has recorded the highest value of 72.886 plot⁻¹, while P2 demonstrated the lowest density with 4.440 plot⁻¹ (Table 1).

The importance value index (IVI) analysis showed that P1 and P2 are dominated by *Acacia decurrens* which recorded the following values, 186.04% (which is 93% from the total IVI value in the plot) and 156.52% (78% from the total IVI value), respectively (Fig. 2). P3 and P4 attained different IVI from P1 and P2, where P3 is dominated by *Pinus merkusii* with IVI value of 113.79 (56%) and *A. decurrens* with IVI value of 80.13 (40% from IVI total in the plot). P4 showed similar IVI with P3, where the plot is dominated by *P. merkusii* (107.67 or 54%) and *A. decurrens* (83.13 or 42%). Amongst the plots, P5 displayed a relatively even values of IVI among the species. Fig. 2 also shows that several species which recorded IVI values of more than 10%, and the species are *A. decurrens*, *A. villosa*, *Cincona rubecea*, *Erythrina hypaporus*, *Euophorbia ciacembus*, *Ficus kubeba*, *Psidium guajava*, *Palotus* sp, *P. merkusii*, *Schima wallichii* and *Trema* sp.

Generally, the species distribution of the early succession can be categorized as clumped, regular or random. The distribution of *A. decurrens* can be recognized as clumped, whereas *P. merkusii* displayed regular character, and other species are distributed randomly. Based on the spatial distribution analysis, *A. decurrens* individuals in P1, P2, P3 and P4 are distributed in the form of clump with the index of dispersion (IE) of more than 1.29 and the agglomeration index (R) close to zero (0) (Table 2). Similarly, the average space between individuals ranged from 0.12 to 0.35 m. On the other hand, the spatial distribution of *A. decurrens* in P5 can be considered as regular with IE and R of 1.29 and 4.345, respectively. These data suggest that the *A. decurrens* domination in P5 is lower than P1, P2, P3 or P4.

Table 2 also shows that *P. merkusii* is randomly and regularly distributed. The spatial distribution of the species in P2, P4 and P5 is considered as regular with IE between 1.34 to 1.388, and R between 2.547 to 7.606. Conversely, in P3, the distribution pattern of the species is random (IE, R < 2.15 (R) and average space = 0.94 m).

There is an inverse relationship between density and diameter (dbh) of *A. decurrens* in P1, P2, P3 and P4. The relationship in P1 and P4 is significant (at p<0.05) with coefficient of correlation (r) -0.77 and -0.77, respectively. However, there is no significant correlation (p>0.05) in P2 and P3 with coefficient of correlation -0.43 and -0.58, respectively. Nonetheless, in general any value r>0.3 (or -0.3) means that the correlation is strong. Relation pattern density of P1 with axis on 50 to 100 thousands tree ha⁻¹ with diameter 1.5 to 3 cm. Relation of P2 has center on density between 2 to 6 thousands tree ha⁻¹ with diameter 0 to 1.5 cm. The pattern relation of P3 midpoint on density 5 to 15 thousands tree ha⁻¹ with diameter 0.5 to 3.5 cm. Whereas P4 has pattern of center relation on density 2 to 6 thousands tree ha⁻¹ with diameter 3 to 7 cm (Fig. 3A, 3B, 3C and 3D).

Table - 1: Recapitulation of richness, heterogeneity, evenness and density

Plot	Richness	Heterogeneity	Evenness	Density
P1	1.907 ^a	0.029 ^a	0.041 ^a	72.886 ^e
P2	2.140 ^{ab}	0.084 ^{ab}	0.101 ^b	4.440 ^a
P3	2.300 ^b	0.131 ^b	0.150 ^b	10.660 ^d
P4	2.500 ^b	0.277 ^c	0.252 ^c	7.920 ^c
P5	3.300 ^c	0.598 ^d	0.626 ^d	5.060 ^b

Note: Means followed by different letters indicate significant at p<0.05, according to Duncan's multiple range test

Table - 2: Space, dispersion and agglomeration index of *A. decurrens* and *P. merkusii*

Plot	Species	Average of space (m)	Dispersion index (IE)	Agglomeration index (R)
P1	<i>A. decurrens</i>	0.122	6.822	0.026
	<i>P. merkusii</i>	n/a	n/a	n/a
P2	<i>A. decurrens</i>	0.350	3.226	0.383
	<i>P. merkusii</i>	5.379	1.340	7.606
P3	<i>A. decurrens</i>	0.174	5.638	0.159
	<i>P. merkusii</i>	0.937	1.558	0.972
P4	<i>A. decurrens</i>	0.296	4.726	0.353
	<i>P. merkusii</i>	1.279	1.388	2.547
P5	<i>A. decurrens</i>	5.829	1.290	4.345
	<i>P. merkusii</i>	2.110	1.362	5.210

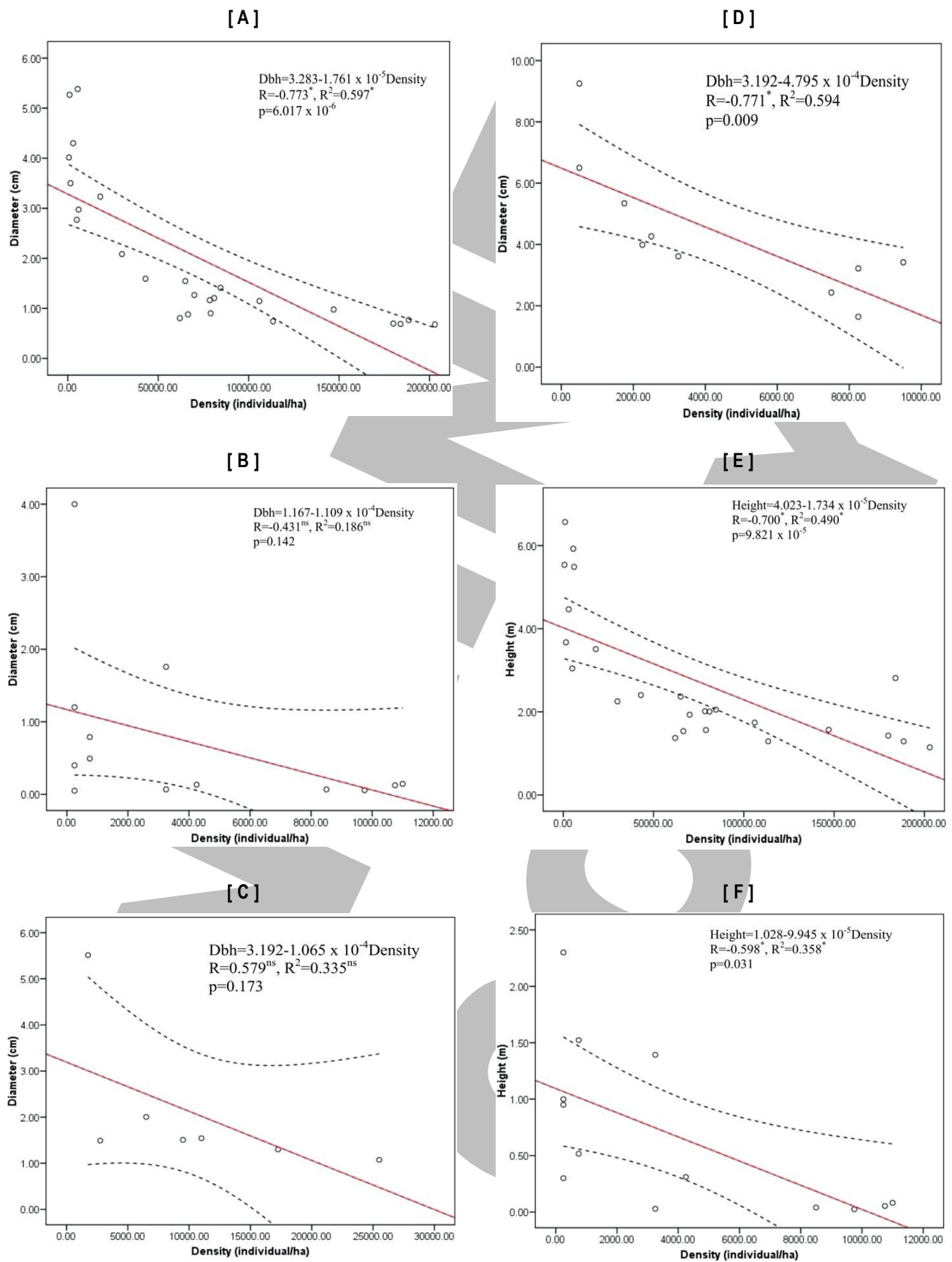
n/a: Not available

The relation *A. decurrens* between density and height at P1, P2, P3 and P4 are inversely proportionate. P1, P2 and P3 showed significant relation (p<0.05) on density and height with r-values of -0.7, -0.6 and -0.64, respectively. The species in P4, on the hand showed no significant relation (p>0.05) with r of -0.35. The pattern relation of P1 midpoint on density 50 to 100 thousands tree ha⁻¹ with height 2 to 3.5 m. P2 has center relation on density 2 to 6 thousands tree ha⁻¹ with height 0.25 to 1 m. Relation pattern of P3 with axis on density 5 to 15 thousands tree ha⁻¹ with height 2.5 to 5.5 m. Whereas P4 has axis relation on density 2 to 6 thousands tree ha⁻¹ with height 4.25 to 7 m (Fig. 3E, 3F, 3G, 3H).

Diameter and height of *A. decurrens* on P1, P2, P3 and P4 have undeviating proportional relation. The relation both P1, P2, P3 and P4 are significant (p<0.05) with coefficient of correlation (r) every plot 0.93; 0.86; 0.97 and 0.64. The pattern relation of P1 midpoint on height between 2.5 to 3.5 m with diameter 0 to 2 cm. Relation of P2 has center on height between 0.1 to 1 m with diameter 0.1 to 1 cm. Relation pattern of P3 with axis on height between 2 to 3 m with diameter 1 to 2 cm. Whereas at P4 has center relation on height between 5 to 6.5 m with diameter 3 to 5 cm (Fig. 3I, 3J, 3K and 3L).

Discussion

The species diversity (in this study on GMNP), which was developed after two years of eruption, showed that the species have ability to grow is limited. The result is somewhat similar to the post-eruption diversity on Mount St. Helens (in the southwest region of the Washington state). Dale *et al.* (2005) reported that plant establishment and spread were slow throughout the first years after the eruption with the average cover of the plots was less than 1%. Geographically, post-eruption GMNP is dominated by rock, coral



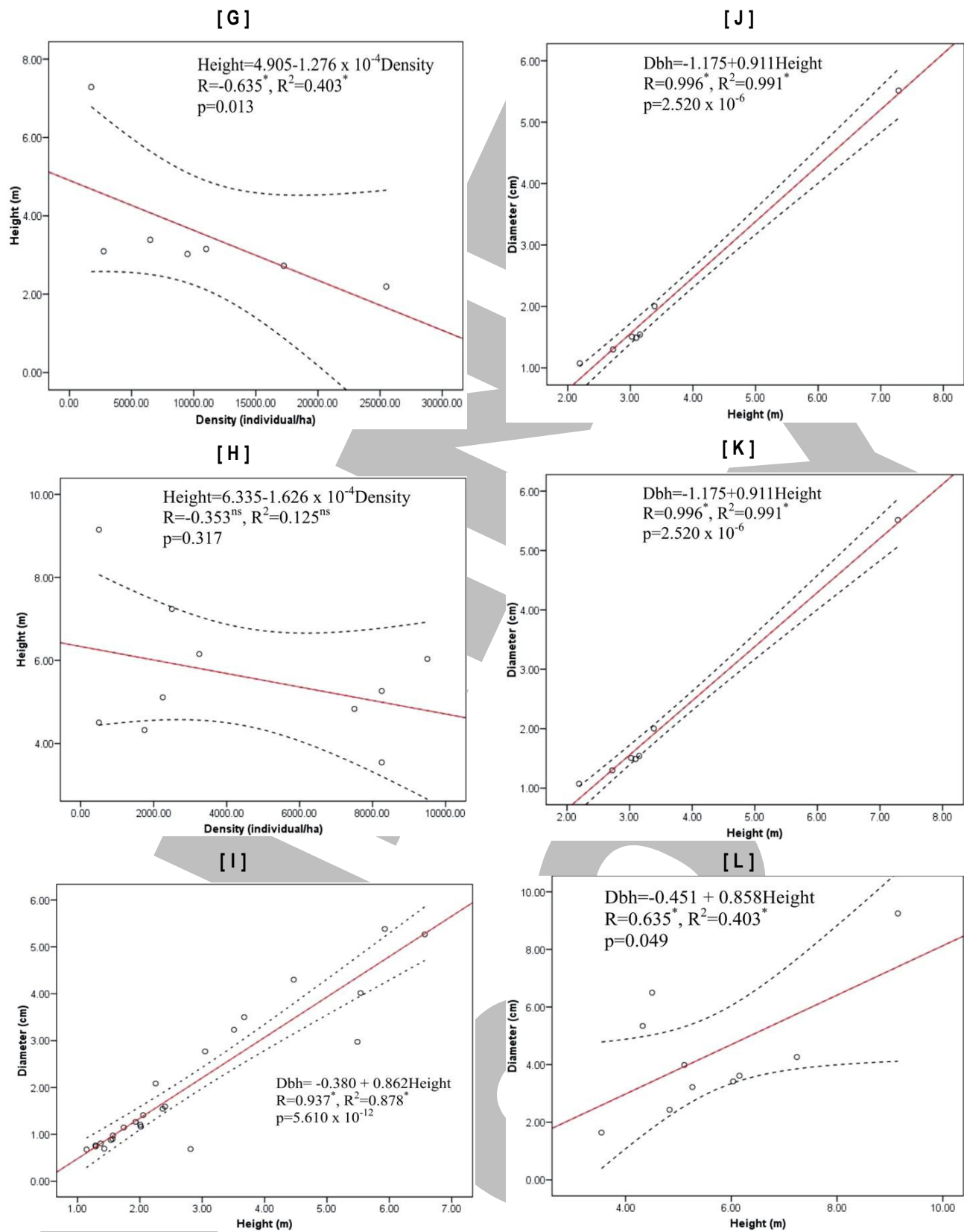


Fig. 3: Relation density and dbh of *A. decurrens* at P1(A), P2(B), P3(C) and P4(D); Relation density and height of *A. decurrens* on P1(E), P2(F), P3(G) and P4(H); Relation dbh and height of *A. decurrens* on P1(I), P2(J), P3(K) and P4(L)

and sand, which in turn becoming a limiting factor for plant growth to its poor nutrient level, poor water-holding capacity and unfavorable temperature. According to Charbonnier and Gertisser (2008), the post-eruption temperature of clouds of super-heated gases (or *awan panas*) was approximately 165-400°C.

The trend of heterogeneity has similarity with species richness. Species arrangement that growth on early succession more straight forward to homogeneity (P1, P2, P3 and P4) whereas P5 has trend more heterogenic. Evenness value at P5 has similarity tendency with heterogeneity value thus P1 until P4 showed a species dominant. It is usually known that species richness is positively connected with species abundance (Denslow, 1995) and in this study the dominant species are *A. decurrens* and *P. merkusii*. Plant communities are frequently characterized by their dominant (Neave and Norton, 1998).

The trend of species diversity in P1 to P4 is similar, and it is significantly different from P5. In the early succession, successful recruitment into these short-lived sites depends on seed delivery (Tumbull *et al.*, 2000), and it is usually known that species richness is positively connected with area, and ecological heterogeneity have strong effect on species diversity (Whitmore, 1998).

One of the unique characteristics from species distribution on early primary succession in GMNP is the distribution pattern of woody plant such as *A. decurrens*, which is clumped in a very small space of 10-30 cm. This phenomenon may have contributed to the inverse relation between density and diameter, where many individuals of the species are small in diameter. Similarly, is the relation between density and height. This inverse relation is basically a common phenomenon, for example, Condit *et al.* (1994) have reported that the tree density average is often negatively linked with the mean tree size. However, the level of stand density showed different trend from species diversity. P1 has recorded the highest of level density, whereas the levels in both P2 and P5 are much lower than the others plots. In contrast, height and diameter show relation undeviating proportional. The distribution of *P. merkusii* is different with *A. decurrens* such as more tendencies to regular nonetheless any trend to random. Based on the data of *P. merkusii* has not enough yet up to the trend of relation density and growth unknown.

The post-eruption species diversity in GMNP showed that the number of species adaptive to the site is limited, and the site is dominated by *A. decurrens* and *P. merkusii*. The distribution pattern of *A. decurrens* is clumped, whereas *P. merkusii* has regular and random patterns. In term of growth (both diameter and height), the growth of *A. decurrens* is inversely proportionate between density and diameter and height. This information suggests that the species diversity, which is dominated by pioneer trees species can support more population (Huang *et al.*, 2003), and the habitat developed by the species can become a safe site in the future (Kimmins, 1997), especially to facilitate growth the others species. The large population of *A. decurrens* will be very important for community surrounding GMNP because it is a species potential for charcoal to supply local energy. The result is supported by Singh (2002) which says that biodiversity is fundamental for supporting not only ecosystem function and stability but also human survival and economic.

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