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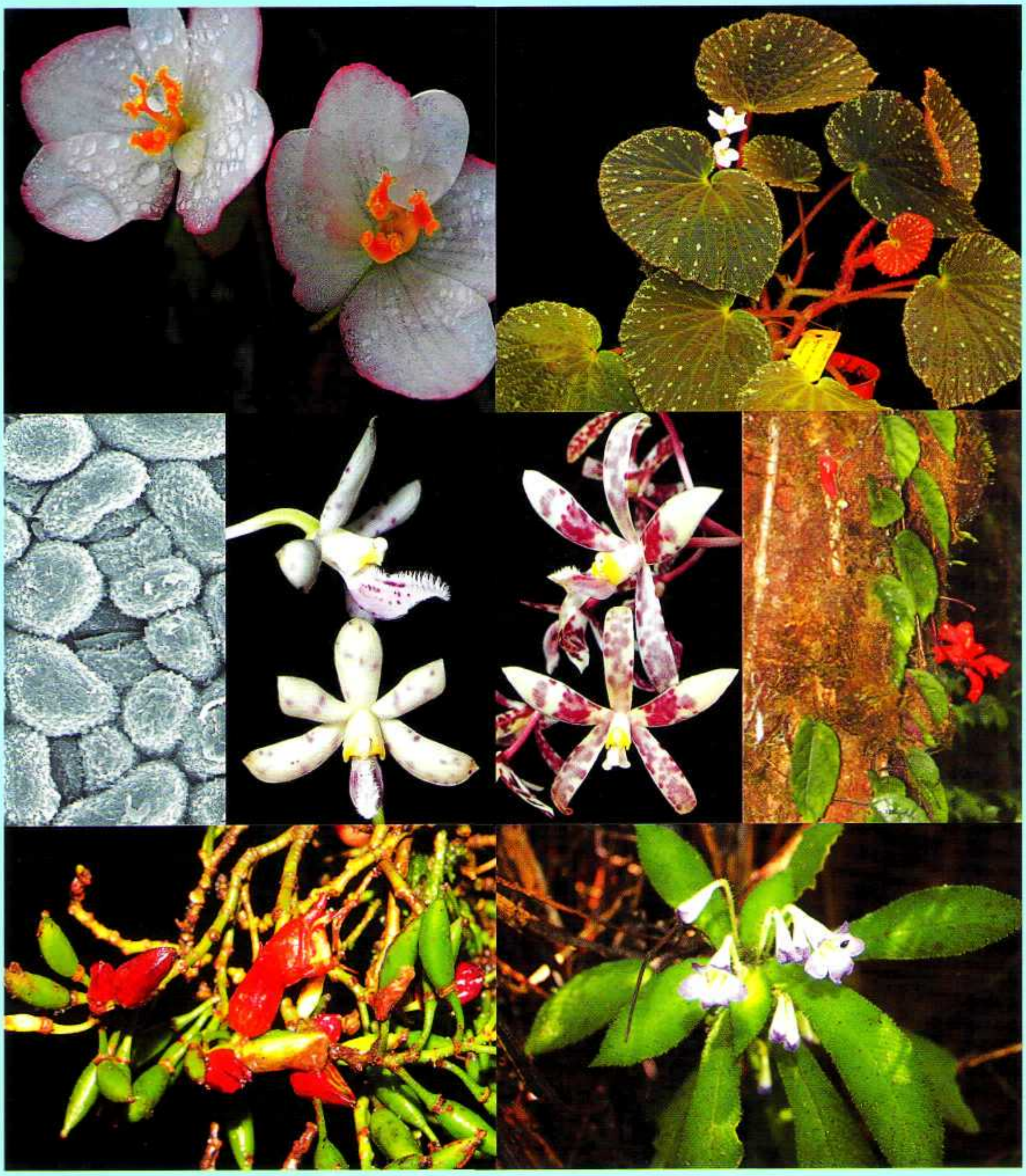

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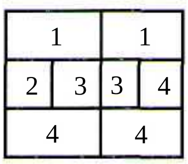

Cover images: 1. *Begonia holosericeoides* (female flower and habit) (Begoniaceae; Ardi *et al.*); 2. Abaxial cuticles of *Alseodaphne rhododendropsis* (Lauraceae; Nishida & van der Werff); 3. *Dipodium puspitae, Dipodium purpureum* (Orchidaceae; O'Byrne); 4. *Agalmyla exannulata, Cyrtandra coccinea* var. *celebica, Codonoboea kjellbergii* (Gesneriaceae; Kartonegoro & Potter).

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THE EFFECT OF LAND USE HISTORY ON NATURAL FOREST REHABILITATION AT CORRIDOR AREA OF GUNUNG HALIMUN SALAK NATIONAL PARK, WEST JAVA INDONESIA

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ABSTRACT

ROSLEINE, D., SUZUKI, E., SUNDAWIATI, A., SEPTIANA, W. & EKAWATI, D. 2014. The effect of land use history on natural forest rehabilitation at corridor area of Gunung Halimun Salak National Park, West Java Indonesia. *Reinwardtia* 14(1): 85 – 99. — Corridor area of Gunung Halimun Salak National Park was degraded and fragmented by human activities. However, little is known about recovery process in tropical degraded forest under different land use history. To clarify vegetation structure and forest recovery related to land use history we placed 22 plots (11 of 10 × 10 m^2 in abandoned plantation and 11 of 20 × 20 m^2 in secondary forest, respectively). DCA (Detrended correspondence analysis) discriminated the plots into three community groups. *Swietenia macrophylla – Agathis dammara* community in abandoned plantation where had a land use history of clear felling. *Maesopsis eminii – Cyathea* spp. community had a history of severe human disturbance. Fagaceae – *Schima wallichii* was in less disturbed forest. Below the plantation canopy, light tolerant species, weeds, grasses and fern of *Dicranopteris linearis* were dominant. Some exotic plants spread to the disturbed forest. The less disturbed forest in distant area from village remained in good condition as indicated by dominancy of old forest species. For the forest rehabilitation in severely degraded area, human intervention by planting native species can be suggested to avoid invasive species occupancy as well as accelerate forest recovery.

Key words: Gunung Halimun Salak National Park, land use, tropical forest rehabilitation.

ABSTRAK

ROSLEINE, D., SUZUKI, E., SUNDAWIATI, A., SEPTIANA, W. & EKAWATI, D. 2014. Pengaruh pemanfaatan lahan pada masa lalu terhadap rehabilitasi hutan alam di koridor Taman Nasional Gunung Halimun Salak, Jawa Barat Indonesia. *Reinwardtia* 14(1): 85 – 99. — Koridor Taman Nasional Gunung Halimun Salak mengalami degradasi dan fragmentasi habitat yang cukup serius akibat aktivitas manusia. Sebanyak 22 plot (11 plot berukuran 10 × 10 m^2 di bekas hutan tanaman dan 11 plot berukuran 20 × 20 m^2 di hutan sekunder) disebar untuk menganalisa struktur vegetasi dan melihat proses pemulihan lahan hutan yang dihubungkan dengan sejarah penggunaan lahan yang berbeda-beda di kawasan ini. DCA (*Detrended correspondence analysis*) mengelompokkan tiga tipe komunitas yang ditemui di kawasan koridor, yaitu komunitas *Swietenia macrophylla – Agathis dammara* di lahan bekas hutan tanaman, *Maesopsis eminii – Cyathea* spp. di hutan yang sangat terganggu, dan Fagaceae – *Schima wallichii* di hutan sekunder yang mengalami sedikit gangguan. Jenis-jenis tumbuhan yang toleran terhadap cahaya, gulma, rumput dan paku *Dicranopteris linearis* mendominasi lantai hutan tanaman yang telah ditinggalkan, namun beberapa tumbuhan eksotis yang dapat mengancam keanekaragaman hayati ditemukan di hutan sekunder yang terganggu. Sisa hutan alami berada di lokasi yang jauh dengan pemukiman penduduk dan masih didominasi oleh tumbuhan asli hutan pegunungan. Berdasarkan hasil penelitian tersebut, rehabilitasi hutan di kawasan yang sangat rusak sebaiknya dibantu oleh manusia dengan menanam jenis-jenis tumbuhan asli untuk menghindari masuknya tumbuhan invasif, sehingga mampu mempercepat proses pemulihan hutan.

Kata kunci: Taman Nasional Gunung Halimun Salak, pemanfaatan lahan, rehabilitasi hutan tropis.

INTRODUCTION

Deforestation in Indonesia is high due to illegal logging, forest fire, forest conversion and agriculture as the consequences of economic development (Nawir *et al*., 2007; FAO, 2010; FAO, 2011). Considering the negative impacts of forest loss to human life and environment, government and local people implemented rehabilitation program by reforestation to restore the forest function (Nawir *et al*., 2007; Setiawan & Sulistyawati, 2008; FAO, 2010). High population number in Java Island forced forest clearance especially in lowland area. The remaining natural forests are distributed mostly in remote mountain areas with less human activity (Thiollay & Meyburg, 1988; Smiet, 1992; Galudra, 2003). The protected forests and national parks are essential to reduce deforestation. However, the fact showed that increasing demand of food and timber aligning with high population threats the conservation area including Gunung Halimun Salak National Park (GHSNP) as the largest natural montane forest in Java.

GHSNP is susceptible to human disturbance because of the history of community settlement since colonial era (Galudra *et al*., 2005). Besides protecting water catchment area for several big cities near the national park, it is also important to conserve endangered animals such as Javan gibbon (*Hylobates moloch*), Javan leopard (*Panthera pardus melas*) and Javan eagle (*Spizaetus bartelsii*) (Galudra, 2003; Galudra *et al*., 2005; Takahashi, 2006; Ario, 2007; Dewi *et al*., 2007; Rinaldi *et al*., 2008; Yumarni *et al*., 2011). Therefore, the Indonesian government, by the Ministry of forestry decree No.l75/Kpts-11/2003 increased the protected area Mount Halimun National Park (40.000 ha) to be merged with Mount Salak Reservation area as Gunung Halimun Salak National Park (HSNP) with total area 113.357 ha to reduce forest loss (Galudra, 2003; Takahashi, 2006; Ario, 2007; Dewi *et al*., 2007; Rinaldi *et al*., 2008; Yumarni *et al*., 2011). This large areas cover not only forest but also villages, tea plantation, agriculture and scrubland, which reflects the land use history in the past (Rinaldi *et al*., 2008; GHSNPMP-JICA, 2009). Unfortunately, these degraded areas are mainly located in corridor between Gunung Halimun and Salak area.

Halimun and Salak corridor about 7.17 km long and 1.99 km width is essential area for animal conservation because genetic exchange is allowed and the endangered animals use this place for their habitat, breeding, movement and foraging area (Sugardjito *et al*., 1997; Cahyadi, 2003; Rinaldi *et al*., 2008). Moreover, corridor has rivers that are important for water supply to Sukabumi and Bogor district (Rinaldi *et al*., 2008; GHSNPMP-JICA, 2009; Yumarni *et al*., 2011). Nevertheless, natural forest in corridor decreased from 667 ha to 319 ha within 11 years from 1990 to 2001(Cahyadi, 2003). Based on ikonos satellite image in 2004, corridor areas was covered by natural forest, secondary forest, bush, cultivation area, *Calliandra calothyrsus*, *Schima wallichii* and tea plantation. The area of secondary forest, primary forest and plantation in corridor were 759.06 ha, 268.56 ha, and 42.05 ha respectively (Cahyadi, 2003; Rinaldi *et al*., 2008; GHSNPMP-JICA, 2009). Some studies on javan gibbon population in corridor reported that decreasing tree canopy significantly affected the population number because this arboreal animal needs canopy for their movement and foraging (Rinaldi *et al*., 2008; Yumarni *et al*., 2011).

Therefore, rehabilitation of degraded area in corridor is necessary to restore its function. Integrated information including ecology, social and economics study is needed to design forest rehabilitation management system. Study on spatial analysis for forest structure and function at corridor area of GHSNP has been conducted by Cahyadi (2003). Species check list of flora and fauna (Rinaldi *et al*., 2008; GHSNPMP-JICA, 2009), analysis of the effect forest degradation on javan leopard (Ario, 2007), javan gibbon (Dewi *et al*., 2007; Yumarni *et al*., 2011) have been conducted to support conservation of endangered animals at corridor area of GHSNP. However, there are only few studies on community structure and successional pattern in abandoned lands after human activities. Thus the purpose of this study is to clarify the present vegetation composition in corridor area from plot survey and discuss the effect of previous land use history on the vegetation. This analysis will give scientific information to restore the natural vegetation in corridor area in the future.

Information of natural forest including vegetation (Simbolon & Mirmanto, 1997; Suzuki *et al*., 1997; 1998; Alhamd & Polosakan, 2011) and flora (Suzuki, 2002; Polosakan, 2011; Priyadi *et al*., 2010) were available. This scientific information is essential as reference condition to confirm the successful of rehabilitation process.

STUDY SITE AND METHODS

Study site

Corridor area of Mount Halimun Salak National Park geographically located at 06°44'S to 06°45'S and 106°35'E to106°38'E. The remaining forest in

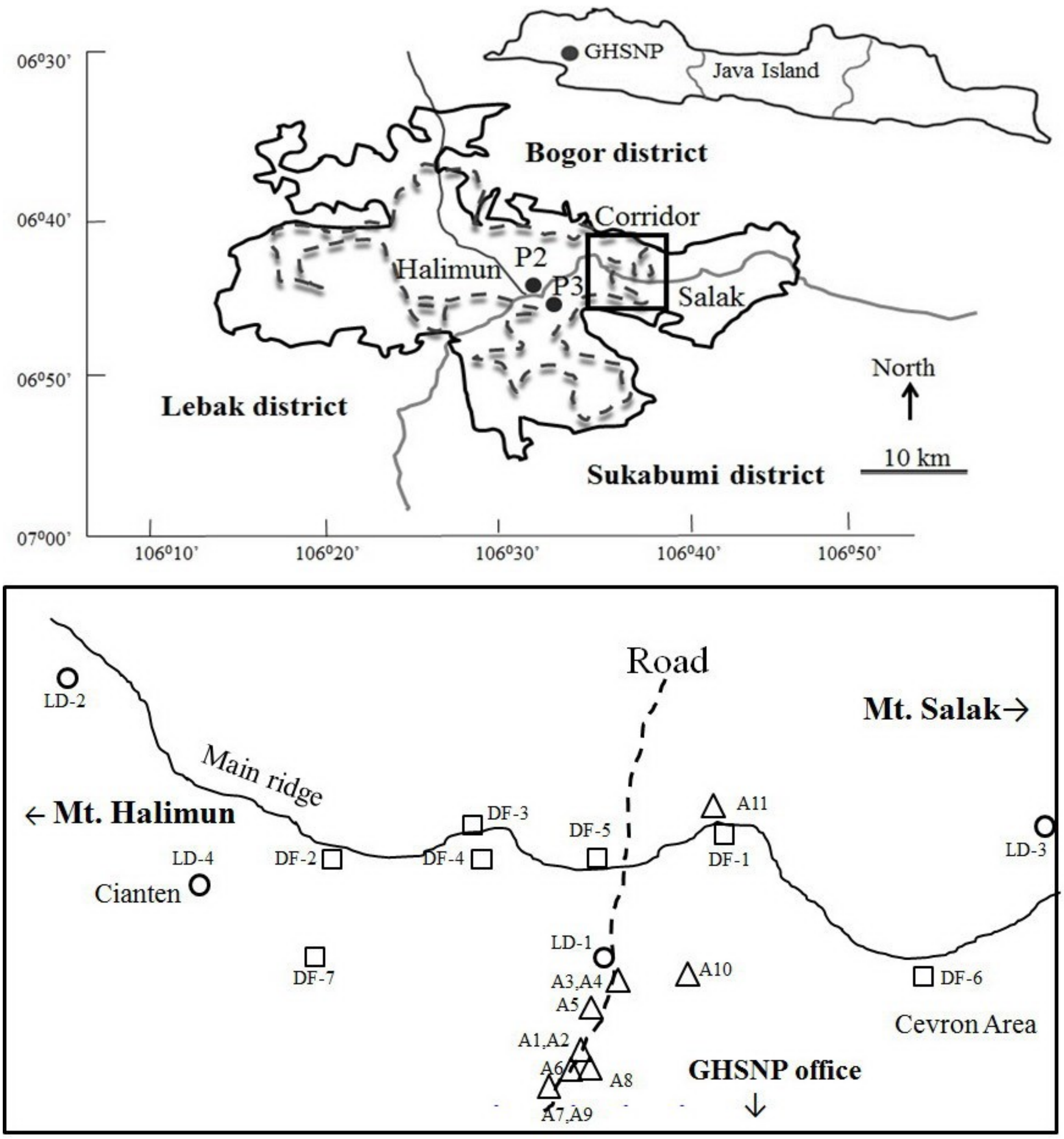

Fig. 1. Location of Gunung Halimun Salak National Park within three boundaries of Bogor, Sukabumi and Lebak District, West Java, Indonesia. The broken line was the old border and stright black line is new border of national park. Vegetation survey was conducted at the plots of abandoned plantation (A1-11), disturbed forest (DF1-7) and less disturbed forest (LDF1-4) in corridor area within area inside the box.

corridor area approximately 318.985 ha (Cahyadi, 2003; Rinaldi *et al*., 2008; GHSNPMP-JICA, 2009; Yumarni *et al*., 2011). Administratively it located within two boundaries of Sukabumi and Bogor District, West Java, Indonesia (Fig. 1). The altitude of our study area ranges from 850 m to 1100 m above sea level, which classified as submontane forest zone (Simbolon & Mirmanto, 1997). Topography of corridor area varies from flat to the very steep, where corridor at Salak area is more flat than Halimun area. As described by Rinaldi *et al*. (2008), soil at corridor area dominated by association of reddish-brown latosol and brown latosol.

History of Gunung Halimun Salak National Park

Galudra *et al*. (2005) identified that the deforestation in Halimun-Salak area occurred since 1700s under the colonial era to establish coffee plantation. However, this plantation failed due to plant disease and it initiated the degradation of natural forest. The natural forests in GHSNP about 22.000 ha (25%) were reduced seriously because of land use conversion and timber harvesting during 1998-2001 (Prasetyo *et al*., 2006).

By the decree of Ministry of Agriculture No. 40/Kpts/Um/1/1979 about 40.000 ha Halimun area was declared as nature reserve for conservation and then altered to national park in 1992. The remaining forest areas (73.357 ha) were declared as production and protected forest. As an effort to reduce forest loss, Indonesian government increased conservation area by merging Halimun National Park and Salak Reservation area (113.357 ha) in 2003 including production forest that previously managed by PERHUTANI. The social conflicts related to land ownership, intensive land use and ongoing timber exploitation by rural community are major problems for the management of this national park (Smiet, 1990; Galudra *et al*., 2005; Rinaldi *et al*., 2008; GHSNPMP-JICA, 2009).

The corridor of Gunung Halimun Salak National Park

The corridor area was relatively covered by natural forest during 1983-1989. However, corridor fragmentation was started in 1990 due to forest clearance about 35 ha for timber production. The deforestation spots increased especially in south part of corridor. It was recorded that more than 100 ha of forest disappeared up to end of 1900s. The fragmentation and degradation disrupt the function of corridor as connector for endangered animals within two ecosystems. Recently, the remaining old forest in corridor located in high altitude and steep area (Prasetyo *et al*., 2006).

The corridor area was managed by stated owned company PERHUTANI as production forest before it declared as part of national park since 2003 (Galudra *et al*., 2005; Rinaldi *et al*., 2008; GHSNPMP-JICA, 2009). The Mahogany (*Switenia macrophylla*) as the most favored plantation tree in tropical forest (Richardson, 1998; Otsamo, 2001), *Agathis damara* and *Altingia excelsa* were planted in corridor for timber production (Cahyadi, 2003). The pressure from community on land extension for those purposes decreased forest covers seriously at corridor.

The corridor area is defined as wet climate type B based on Schmidt and Ferguson climatic classification. The average of annual rainfall varied from moderate (4000 – 4500 mm) to high (4500 – 5000 mm). Rain season occurred in October to April and dry season started from July to September. Humidity at corridor reached 80% (Cahyadi, 2003). Mean daily temperature at Cianten (924 m alt.) varied from 24.7 to 26.5 °C, maximum and minimum temperature ranged from 31-34.8 °C and 18.3-23.4 °C, respectively (Djuwansah, 1997).

Corridor area can be classified into four groups of plant communities from west to east: Halimun area dominated by *Castanopsis acuminatissima* – *Schima wallichii*, western patch dominantly covered by *S. wallichii* – *Maesopsis eminii*, eastern patch covered by *Quercus gemmeliflora* – *S. wallichii*, and Salak area dominated by *Euodia latifolia* (syn. *Melicope latifolia*) – *S. wallichii* (Rinaldi *et al*., 2008). The vegetation composition in each part of corridor reflected disturbance intensity in this area. The old forest was dominated by *Engelhardia serrata*, *Castanopsis* spp., *Quercus* sp., *Lithocarpus* spp., *Litsea* spp., and member of Myrtaceae. The degraded parts in corridor area are mostly covered by pioneer and secondary vegetation such as *Macaranga* spp., *Homalanthus populneus*, *Mallotus* sp., *Ficus sinuata*, *F. hirta* and *F. padana*. The most degraded area occupied by grass *Imperata cylindrica* and shrubs (Cahyadi, 2003; Harada, 2003; Rinaldi *et al*., 2008).

Sampling methods

Vegetation survey was conducted in June and October 2011 at 22 sites, covering abandoned plantation (A1-A11), secondary forest (D1-D7 and LD1-LD4) to represent community types in corridor area (Fig. 1). We defined three layers of vegetation as tree, seedling and herb layer. At abandoned plantation, diameter at breast height (*DBH*, cm) and height (*H*, m) of tree as woody species taller than 130 cm were recorded within 11 plots of 10 × 10 m for every species. However, in the secondary forest areas, 11 plots were enlarged into 20 × 20 m to record tree bigger than 4.8 cm in *DBH*.

As a reference area for vegetation development at corridor due to natural succession, we recorded tree of two 1- ha permanent plots (P2 and P3) in old forest Halimun area (Suzuki *et al*., 1998).

In each plot of 10 × 10 m, 9 sub-quadrates (each 2 × 2 m) were set to measure height and basal diameter (D_{20}) at 20 cm aboveground for every stem of seedling, which is defined as woody species lower than 130 cm. For herb species, we recorded coverage (% of plot area) within the same area of seedling.

Data analysis

Relative dominance (*Rdo*, %) of tree, shrub, sapling and herb species were calculated. The aboveground biomass was estimated using allometric correlation method (Yamakura *et al.,* 1986). For tree and shrub, *Rdo* was defined as cross-sectional area of the tree at a point 130 cm divided by total basal area (*BA*, m^2 ha^{-1}). However, we used cross-sectional at a point 20 cm (D_{20}) as basal area for seedling. The *Rdo* of herb determined as the percentage of vegetation coverage divided by total coverage. The detrended correspondence analysis (DCA) method of Hill & Gauch (1980) was used to analyze community types and successional pattern among corridor plots based on relative dominance of all species.

We also calculated two tree biodiversity indices: the Shannon-Wiener index (*H*', Krebs, 1989) and Fisher's alpha (α, Fisher, 1943). The componens combined in Shannon-Wiener index are number of species (s) and proportion of total sample belonging to *i*th species (p*i*) as followed (Krebs, 1989).

$$H' = \sum_{i=1}^{s} pi \ln pi$$

The number of species (*S*) and the number of individual (*N*) are required to calculate Fisher's alpha index as defined by the following formula (Fisher, 1943):

$$S = \alpha \ln (1+N/\alpha)$$

RESULTS

The detrended correspondence analysis (DCA)

Our study recorded 364 species (scientifically unidentified species were distinguished with local name) within 22 plots from various life forms such as tree (161 sp.), shrub (88 sp.), and herb (115 sp.). The relative dominance data of all species among plots were combined to analyze the community similarity and disturbance intensity through successional process in corridor and Halimun area. The first and second scores of DCA are displayed on Fig. 2. The eigenvalues from DCA1 to DCA 4 are 0.78, 0.54, 0.41, and 0.3, respectively. The abandoned plantations were distinguished from disturbed and less disturbed forests by the value of DCA1. Within abandoned plantations, DCA 1 value reflects the disturbance intensity. Severe degradation areas were grouped in high DCA1 value and less-degraded areas were placed in low DCA1 value. Within abandoned plantation there were two plots (A7 and A10) separated from the others. Plot A7 was located in area with active cultivation and dominated by plantation tree, crops and weeds, while A10 was the longest abandoned plantation, which adjacent to disturbed natural forest.

DCA1 values for two plots in natural forest around Cikaniki (P2 and P3), 11 secondary forests, and A10 were less than 0. The DCA2 values of disturbed forests were less than 0 while the less disturbed forest were more than 0. Then we separated the secondary forest plots into two types. They are seven plots (DF1 to DF7) as disturbed forest plots and four plots as less disturbed forest (LD1 to LD4). The sampling area for degraded forest located at central part of corridor area, while the less disturbed forests were sampled randomly at the slope and less accessible forests.

Fig. 3 shows the species score of DCA 1 and 2. The plantation trees, *A. dammara* and *S. macrophylla* had high value of DCA1. The pioneer trees (*Homalanthus populneus*, *Macaranga tanarius* and *M. triloba*), some invasive (*Cinchona pubescens*, *M. eminii* and *C. calothyrsus*) and high-climbing bamboo (*Dinochloa scandens*) had negative value both in DCA1 and DCA2, while climax species such as *Quecrus, Castanopsis* and *Platea* had negative value of DCA1 and positive value of DCA2. Base on these values, the study areas were composed by three communities as *S. macrophylla – A. dammara* community in abandoned plantation (plots of A1 to A11), *M. eminii – Cyathea* sp. at disturbed forest (plots of D1 to D7) and *C. acuminatissima – S. wallichii* in less disturbed forest (plots of LD1 to LD4) as shown in Table 1. The areas adjacent with local people settlements and accessible forest were severely degraded due to agriculture, fuel wood collecting and illegal logging. However, good condition of forest remaining at the steep places and/or far from local community.

Abandoned plantation (ABP)

This area had been the production forest and abandoned after declared as part of national park. The abandonment periods were varied among 11 plots from 1 to 30 years and it depends on the intensity of agriculture activity. Local people had been allowed to cultivate at some parts of production forest (Galudra *et al*., 2005). Therefore, the cultivation areas still existed and difficult to be reduced because local community rely on agriculture to support their live. As reported by Cahyadi (2003), cultivation area within 11 years increased about 8.8% from 1.356 ha in 1990 to 1.476 ha in 2001. The uniqueness of intensive cultivation (plot A7) can be shown in DCA graph (Fig. 2), that A7 was separated from fallowed plantation by the dominancy of crops (*Capsicum frutescens*, *Coffea arabica*, *Solanum nigrum* and *S. torvum*) and weeds (*Ageratum conyzoides*, *Clidemia hirta*, *Crassocephalum crepidioides*, *Synedrella nodiflora* and *Wedelia trilobata*). In the area without agriculture and less disturbance, abandoned plantation recovered naturally to support wild life conservation.

The abandoned plantation has low tree species richness as implied by low tree diversity indices (Fisher's α and Shannon-Wiener index), but recruitment of woody species relatively high in this

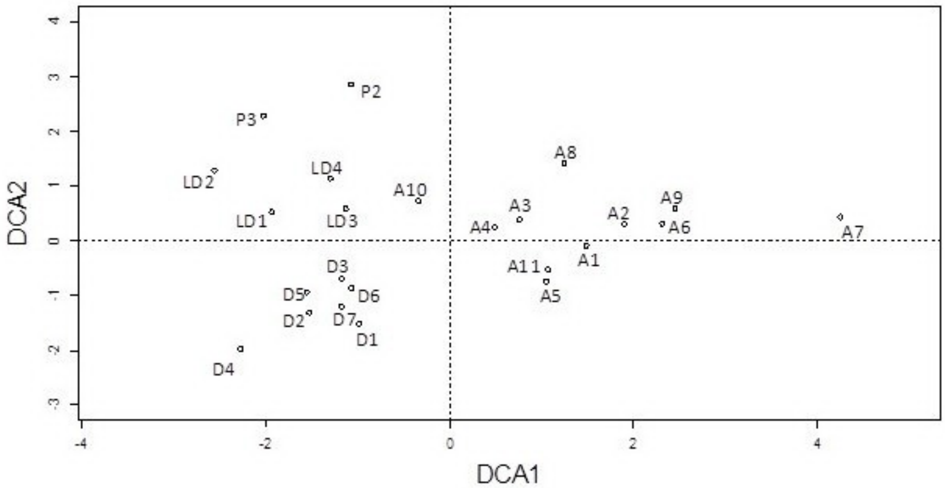

Fig. 2. The ordination of plots in corridor area based on DCA1 and DCA2 value. The abandoned plantations are marked as A (1-11); the disturbed forests are DF (1-7), less degraded forests are LD (1-4), and permanent plots (P2 and P3). The intensive cultivation led to severe degradation at plot A7. The longest abandonment period (A10) has similarity to less disturbed forest due to natural succession.

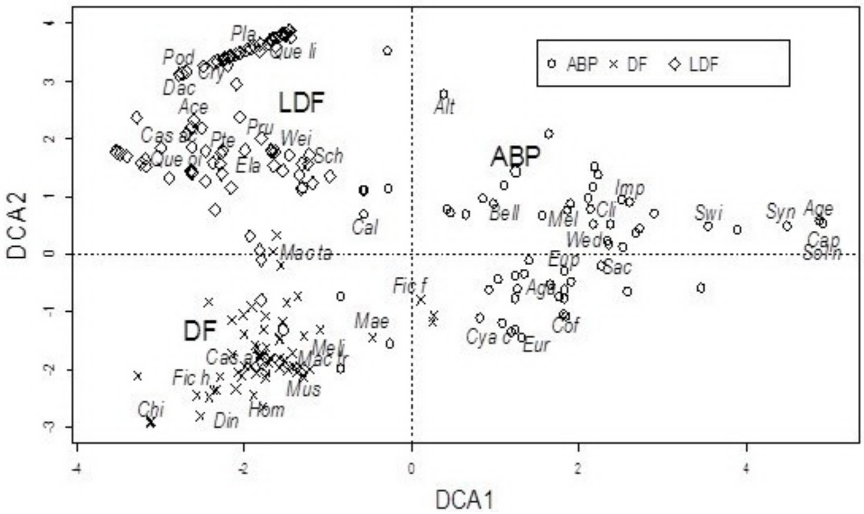

Fig. 3. The ordination of common species in each forest type based on DCA1 and DCA2 value. The vegetation composition reflects disturbance intensity in corridor area. The open area species has high DCA1 value while forest species grouped by lower DCA1 value. The abbreviation of sites and common species were displayed on graph; Abandoned plantation (ABP), Disturbed forest (DF), Less disturbed forest (LDF), *Agathis dammara* (Aga), *Ageratum conyzoides* (Age), *Altingia excelsa* (Alt) , *Bellucia pentamera* (Bell), *Calliandra calothyrsus* (Cal), *Capsicum frutescens* (Cap), *Castanopsis acuminatissima* (Cas ac), *Chinchona pubescens* (Chi), *Clibadium surinamense* (Cli), *Coffea arabica* (Cof), *Cyathea contaminans* (Cya c), *Cyathea* sp. (Cya l), *Dinochloa scandens* (Din), *Eupatorium inulifolium* (Eup), *Eurya acuminate* (Eur), *Imperata cylindrica* (Imp), *Macaranga tanarius* (Mac ta), *Macaranga triloba* (Mac tr), *Maesopsis eminii* (Mae), *Melastoma malabathricum* (Mel), *Musa acuminata* (Mus), *Platea excelsa* (Pla), *Pternandra azurea* (Paz), *Podocarpus neriifolius* (Pod), *Quercus lineata* (Que li), *Quercus oidocarpa* (Que oi), *Saccharum spontaneum* (Sac), *Schima wallichii* (Sch), *Solanum nigrum* (Sol n), *Swietenia macrophylla* (Swi), *Synedrella nodiflora* (Syn), *Weinmannia blumei* (Wei), *Wedelia trilobata* (Wed).

Table 1. The characteristics of abandoned plantation (ABP), disturbed forest (DF), less disturbed forest (LDF) at Halimun Salak corridor area, and reference sites at Halimun (P2 and P3) based on basal area (m^2 ha^{-1}), biomass (ton ha^{-1}), species number of tree (T), Seedling (S), and herb (H), Fisher's α, and Shannon-Wiener index (H').

Site characteristics	Abandoned Plantation (ABP1-11)	Disturbed Forest (DF1 -7)	Less Disturbed Forest (LDF 1-4)	Halimun (P2)	Halimun (P3)
Basal area (m^2 ha^{-1})	15.51	17.47	41.27	40.31	39.66
Biomass (ton ha^{-1})	58.96	71.85	314.94	369.26	291.06
Species richness	(/0.11ha)	(/0.28ha)	(/0.16ha)	(/ha)	(/ha)
Tree*	23	54	47	112	98
Seedling	41	39	47	NA	NA
Herb	71	52	43	NA	NA
Species diversity					
Fisher's α	7.19	20.98	18.46	31.32	23.38
Shannon-Wiener index (H')	3.44	4.45	4.04	5.77	4.61

area (Table 1). Tree layer was dominated by mahogany (*S. macrophylla*, Rdo = 33.4%) and damar (*A. dammara*, Rdo = 21.1%) as main plantation tree (Table 1). The exotic fast growing species such as *Bellucia pentamera* (Rdo = 10.6%) and *M. eminii* (Rdo = 6.9%) seem successfully to establish in this area (Table 2).

Table 2 shows that sufficient amount of light on forest floor led to the dominancy of light-tolerant species *Clibadium surinamense* (Rdo = 17.3%), *Eupatorium inulifolium* (Rdo = 13.7%) and *Melastoma malabthricum* (Rdo = 6.3%). The availability of seedling *Eurya acuminata* (Rdo = 15.3%) indicated that forest species has possibility to establish inside this area. *E. inulifolium* is native to South America, introduced to Java in the 19^{th} and now widely spread from abandoned coffee plantation to degraded forest (Smiet, 1992). Coffee (*C. arabica*, Rdo = 7.7%) and red pepper (*C. frutescens*, Rdo = 4.8%) as high economic value crops were abundant in this area.

Grasses (*Paspalum conjugatum,* Rdo = 8.7%, *I. cylindrica,* Rdo = 7.1%, and *Panicum notatum,* Rdo = 6.8%), ferns (*Selaginella plana*, Rdo = 17.2% and *Dicranopteris linearis*, Rdo = 6.4%) and weedy herbs (*A. conyzoides* Rdo = 4.8%, *W. trilobata* Rdo = 4.5% and *C. hirta* Rdo = 5.5%) formed dense thicket below the plantation tree (Table 2). Among the study areas, abandoned plantation contained higher number of herb species than disturbed and less disturbed forest; 71, 52 and 43 species respectively (Table 1). It was clear that high light intensity below plantation canopy could promote the establishment of herbaceous vegetation.

The disturbed forest (DF)

The human threats including timber and fuel wood exploitation, infrastructure establishment and invasion of exotic species degraded Halimun Salak corridor area seriously, thus forest species number decreased as indicated by low dominancy in this area (Table 2). As reported by Rinaldi *et al*. (2008), forest species dominated corridor approximately 27% due to occupancy of shrub, pioneer and invasive species.

This type of forest was derived from degraded old forest as indicated that forest species component such as *Quercus oidocarpa* remained as the biggest tree in this area, reached 49.6 cm in DBH and 28 m in height. The emergent tree at this site disappeared (Table 2) and now dominated by *M. eminii* (Rdo = 26.26%) to replace forest species such as *Schima wallichii* (Rdo = 5.58%), and *Melicope accedens*, (Rdo = 5.50%). Furthermore, invasion of other exotic species *Calliandra calothyrsus* (Rdo = 6.49%) and quinine tree (*Chinchona pubescens*, Rdo = 5.41%) may harm forest composition in the future (Table 2).

New recruitment of forest and pioneer species was low in degraded area (Table 2). Seedling of exotic species such as *C. pubescens* (Rdo = 8.30%) and *C. hirta* (Rdo = 6.08%), now dominated this area after tree fern *Cyathea* sp. (Rdo = 62.27%).

The herbaceous vegetation at degraded forest was characterized by fern (*Cyathea* sp., Rdo = 8.70%, *D. linearis*, Rdo = 9.46%, and *S. plana*, Rdo = 7.55%), *Freycinetia* sp. (Rdo = 8.78%), *Etlingera coccinea* (Rdo = 8.68%), and bamboo (*Dinochloa scandens*, Rdo = 4.30%) which are relatively tolerant to low light intensity (Table 2).

Table 2. Ten dominance species from each sampling site are displayed to describe the vegetation structure of abandoned plantation (ABP), disturbed forest (DF), less disturbed forest (LDF) and permanent plot (P2 and P3) in corridor and Halimun area. Family name is written as four characters before species name.

Species	Relative dominance (%)				
	ABP	DF	LDF	P2	P3
Tree					
Laur (Huru beunyer)			1.00		
(Huru sereh)		3.51			
(K10738)				1.58	
(Pasang jambe)		4.32			
Arau *Agathis dammara*	21.05	3.61			
Laur *Alseodaphne* (K10807)					2.70
Hama *Altingia excelsa*	2.79		5.73	31.22	5.80
Mela *Bellucia pentamera*	10.55				
Faba *Calliandra calothyrsus*	2.47	6.49	4.35		
Faga *Castanopsis acuminatissima*			40.57		34.00
Faga *Castanopsis cf. tungurrut*				5.14	
Faga *Castanopsis javanica*			1.09	5.68	
Rubi *Chinchona pubescens*		5.41			
Rubi *Coffea arabica*	3.25				
Cyat *Cyathea contaminans*	2.81				
Cyat *Cyathea* sp.		7.91			
Thea *Eurya acuminata*	1.41				
Clus *Garcinia rostrata*					1.65
Rhiz *Gynotroches axillaris*			2.11		
Myri *Horsfieldia glabra*				2.71	
Euph *Macaranga triloba*		2.53			
Rham *Maesopsis eminii*	6.87	26.26			
Ruta *Melicope accedens*		5.50			
Icac *Platea latifolia*				2.66	
Meli *Pternandra azurea*			1.61		1.83
Faga *Quercus* (K10944)					2.65
Faga *Quercus lineata*				7.69	2.76
Faga *Quercus oidocarpa*			4.36		6.56
Thea *Schima wallichii*	8.50	5.88	27.82	10.59	23.31
Meli *Swietenia macrophylla*	33.38				
Myrt *Syzygium* (K10958)[kisirum/jeret]					1.60
Myrt *Syzygium lineatum*				2.93	
Cuno *Weinmannia blumei*			2.94		
Seedling					
Mora *Artocarpus altilis*	2.05			NA	NA
Aral *Arthrophyllum diversifolium*		1.27		NA	NA
Mela *Bellucia pentamera*	4.23			NA	NA
Faba *Calliandra calothyrsus*	7.30		5.40	NA	NA
Sola *Capsicum frutescens*	4.78			NA	NA

Table 2. Ten dominance species from each sampling site are displayed to describe the vegetation structure of abandoned plantation (ABP), disturbed forest (DF), less disturbed forest (LDF) and permanent plot (P2 and P3) in corridor and Halimun area. Family name is written as four characters before species name (continued).

Seedling					
Faga *Castanopsis acuminatissima*		0.92		NA	NA
Faga *Chinchona pubescens*		8.30		NA	NA
Aste *Clibadium surinamense*	17.26			NA	NA
Mela *Clidemia hirta*	5.06	6.08		NA	NA
Rubi *Coffea arabica*	7.70			NA	NA
Cyat *Cyathea* sp.		62.27	58.10	NA	NA
Cyat *Cyathea* sp.2			18.06	NA	NA
Gesn *Cyrtandra sandei*		5.99		NA	NA
Aste *Eupatorium inulifolium*	13.70			NA	NA
Thea *Eurya acuminata*	15.27			NA	NA
Euph *Macaranga triloba*		2.19		NA	NA
Mela *Melastoma malabathricum*	6.28			NA	NA
Arec *Pinanga coronata*			3.42	NA	NA
Rubi *Psychotria varidiflora*		1.25	0.84	NA	NA
Faga *Quercus oidocarpa*			0.82	NA	NA
Thea *Schima wallichii*			1.06	NA	NA
Symp *Symplocos fasciculata*		1.85	2.72	NA	NA
Myrt *Syzygium lineatum*			0.79	NA	NA
Rubi *Urophyllum glabrum*		2.38		NA	NA
Rubi *Urophyllum macrophyllum*			1.37	NA	NA
Herb					
Aste *Ageratum conyzoides*	4.71			NA	NA
Zing *Alpinia* sp.			11.48	NA	NA
Aspl *Asplenium nidus*			3.54	NA	NA
Arec *Calamus* sp.		4.52	4.55	NA	NA
Mela *Clidemia hirta*	5.53			NA	NA
Cyat *Cyathea* sp.		8.70		NA	NA
Glei *Dicranopteris linearis*	6.37	9.46		NA	NA
Arec *Dinochloa scandens*		4.30		NA	NA
Polyp *Diplazium sorzogonense*			4.05	NA	NA
Polyp *Diplazium* sp. 1		5.72		NA	NA
Zing *Etlingera coccinea*		8.68		NA	NA
Pand *Freycinetia*		8.78		NA	NA
Rubi *Hedyothis* sp.	5.24			NA	NA
Poac *Imperata cylindrica*	7.05			NA	NA
Neph *Nephrolepis davallioides*		4.79	9.16	NA	NA
Olean *Oleandra pistilaris*			10.57	NA	NA
Poac *Panicum notatum*	6.75			NA	NA
Poac *Paspalum conjugatum*	8.67			NA	NA
Arec *Pinanga coronata*			3.34	NA	NA

Table 2. Ten dominance species from each sampling site are displayed to describe the vegetation structure of abandoned plantation (ABP), disturbed forest (DF), less disturbed forest (LDF) and permanent plot (P2 and P3) in corridor and Halimun area. Family name is written as four characters before species name (continued).

Species	Relative dominance (%)				
	ABP	DF	LDF	P2	P3
Arec *Plectocomia*			4.10	NA	NA
Sela *Saccharum spontaneum*	4.94			NA	NA
Thely *Selaginella plana*	17.15	7.55	15.28	NA	NA
Acan *Sphaerostephanos* cf. *heterocarpus*		6.62		NA	NA
Acan *Strobilanthes* sp.			4.55	NA	NA
Aste *Wedelia biflora*	4.46			NA	NA

*The species name for unidentified specimens follows the system in Herbarium of Kagoshima University

Table 3. The diameter class of tree (DBH>4.8 cm) at corridor and permanent plots. Small number of big tree (DBH>30 cm) at abandoned plantation (ABP) indicates high intensity of disturbance. The remaining big trees (DBH>30 cm) contribute to high biomass at less disturbed forest (LDF).

Site	Diameter class (cm)					
	<10	10-20	20-30	30-40	40-50	>50
ABP	82	70	13	1	3	0
DF	138	87	21	4	3	1
LDF	126	44	14	13	18	2
P2	652	232	74	45	24	61
P3	764	474	145	65	39	35

Less disturbed forest (LDF)

The community structure as well as permanent plots in Halimun area, *C. acuminatissima* (Rdo = 40.6%) and *S. wallichii* (27.8%) took a role as important species in less disturbed forest (Table 2). The disturbance in this area indicated by invasion of fast growing tree *C. calothyrsus* (Rdo = 4.4%) (Table 2). Even though this forest has low number of tree species, basal area of less disturbed forest was higher than degraded forest and abandoned plantation, *i.e.* 41.27 m^2 ha^{-1}, 17.47 m^2 ha^{-1} and 15.51 m^2 ha^{-1}, respectively (Table 1).

Tree fern of *Cyathea* sp. (Rdo = 58.1%) and *Cyathea* sp. 2 (Rdo = 18.1%) were abundant in seedling layer. Smiet (1992) reported that these species can survive in more shaded place. However, the exotic species of *C. calothyrsus* (Rdo = 3.4%) can survive in any forest condition as indicated by its high recruitment at disturbed and less disturbed area (Table 2). Shade tolerant species dominated herb layer such as fern (*Nephrolepis davallioides*, *S. plana* and *Diplazium sorzogonense*), *Oleandra pistillaris* and *Alpinia* sp. (Table 2).

Permanent plot (P2 and P3)

The communities of both permanent plots were dominated by Fagaceae, Theaceae and Hamamelidaceae (Table 1). P2 had the highest tree species number (113 species) and basal area (40.31 m^2 ha^{-1}) (Table 1). The emergent tree (height > 30 m) at P2 was *Quercus lineata* reached 109 cm in DBH, while in P3 was *S. wallichii* of 82 cm in DBH. The dominant species in P2 permanent plot were *Altingia excelsa* (Rdo = 31.2%) and *S. wallichii* (Rdo = 10.6%), while P3 dominated by *C. acuminatissima* (Rdo = 34%) and *S. wallichii* (Rdo = 23.3%). The species compositions in the permanent plots and less disturbed forest plots were relatively similar, thus they classified as less disturbed forest on DCA analysis (Fig. 2).

DISCUSSION

Forest succession in corridor area

The successional stage in this area can be determined by species composition in each study area. The early successional stages observed in seriously degraded site, particularly in agriculture area. In the area without weeding activity, weed species such as *A. conyzoides*, *Synedrella nodiflora*, *Crassocephalum crepidioides* established below tree plantation. This pattern was similar to the early succession on abandoned cropland in Sabah, where weedy species become dominant soon after abandonment

(Ohtsuka, 1999). In some areas, understory layer is covered by perennial grass *Imperata cylindrica* and *Saccharum spontaneum*. It is suggested that agriculture activity can slow down the forest recovery process because weeding activity prevents colonization of pioneer wood species (Lugo, 1992).

The occupancy of weed was replaced by shrub pioneer species such as *C. surinamense*, *E. inulifolium* and *M. malabathricum* after one or more year abandonment. However, during the process of succession *D. linearis* often invades open area and covers the ground by its dense thicket. At the old abandoned plantation, species richness of pioneer and forest specie is low because of strong competition by the exotic species (*B. pentamera*, *M. eminii* and *C. calothyrsus*).

The succession in disturbed areas refers to forest respond after gaps due to illegal logging. At the degraded forest, pioneer tree and some exotic species well established because they can compete in harsh condition. However, natural tree vegetation has possibility to grow naturally because forest species (*Melicope accedens*, *Weinmannia blumei*, *Schima wallichii*, *Rhodamnia cinerea* and *Prunus arborea*) still remain as seed resource for forest rehabilitation. The less disturbed forests represent mature community in Gunung Halimun Salak National Park. *C. acuminatissima*, *Platea excelsa*, *Neolitse triplinervia*, *Sterculia oblongata* and *Castanopsis javanica* were well conserved in the area with less anthropogenic activity. The availability of forest species at corridor area takes an important role in natural successional process because they are the source of natural vegetation.

The aboveground biomass indicated the respond of vegetation to the anthropogenic disturbance. Biomass in abandoned plantation was produced mainly from tree plantation, but native and invasive species contribute most to biomass in degraded forest (Fig. 4). Though invasive species produced high biomass in degraded area, it does not mean that they are suitable to be planted for forest rehabilitation in corridor because their existence can modify community structure and may threaten the native species. In less disturbed forest where native species were well conserved, they produced high biomass approximately 373.34 ton ha^{-1} (Fig. 4).

Forest rehabilitation and its threats

Human disturbance such as cultivation, development of infrastructure, settlement, illegal logging and fuel wood exploration are thought to be major factors of forest degradation at corridor of GHSNP. The road inside corridor to connect villages facilitated local community to pass through this area and increased alternative access to reach forest. This degraded and fragmented area cannot provide proper habitat especially for endangered species, therefore rehabilitation is required to restore the function of corridor.

Plantation at corridor area may not facilitate forest species establishment as indicated by low dominancy of natural forest vegetation. This was a different result with the other studies (Lugo, 1992; Parrotta *et al*., 1997; Boley *et al*., 2009) that plantation tree might help the establishment of pioneer woody species to accelerate natural succession. The modification of both physical and biological site condition might increase the possibility for seed to be transported from the adjacent remnant forest to germinate at plantation area. In addition, proper plantation must be considered to attract seed dispersers such as bird and bat, thus they can disperse seed from remnant forest to the degraded area. Cusack & Montagnini (2004) reported that plantation could promote forest succession of woody species in understory layer by shading out the grasses, increasing soil nutrient and facilitating shade tolerant species.

Sometimes, the exotic plants are needed to convert harsh condition to be suitable one for the establishment of indigenous species (Lovejoy, 1985). Due to poor understanding of silviculture system in the tropics, some planted exotic species caused major problem to natural ecosystem (Lugo, 1992; Richardson, 2008; Binggeli, 2001). These species could shift the life-form dominance, reduce structural diversity, increase biomass and change nutrient cycle as reviewed from study case in southern hemisphere (Richardson, 2008). In Java Island, *C. calothyrsus* was planted for fuel, fodder and conservation of critical land because it can survive in poor soil condition (Galudra, 2003; Rinaldi *et al*., 2008). But now this species spread tremendously in corridor area. Study by Fukuda (2010) clarified that *C. calothyrsus* inhibited the establishment of native species and delay the forest rehabilitation process.

Human interference and ecological barrier following combination of competition with invasive species, low seed or root stock availability, risk of seed and seedling predation, lack of sustainable microhabitat for seed germiantion and seedling establishment, seasonal drought, soil nutrient limitation, root competition with grases and fern, and periodic fire can suppress successional process (Lugo, 1992; Parrotta *et al*. 1997). Invasion of exotic species (*M. eminii* and *C. calothyrsus*) which can grow in low light intensity, fern (*D. linearis*) and grass (*I. cylindrica*) in corridor area must be considered seriously because they can delay the rehabilitation process. Shono *et al*. (2006) reported

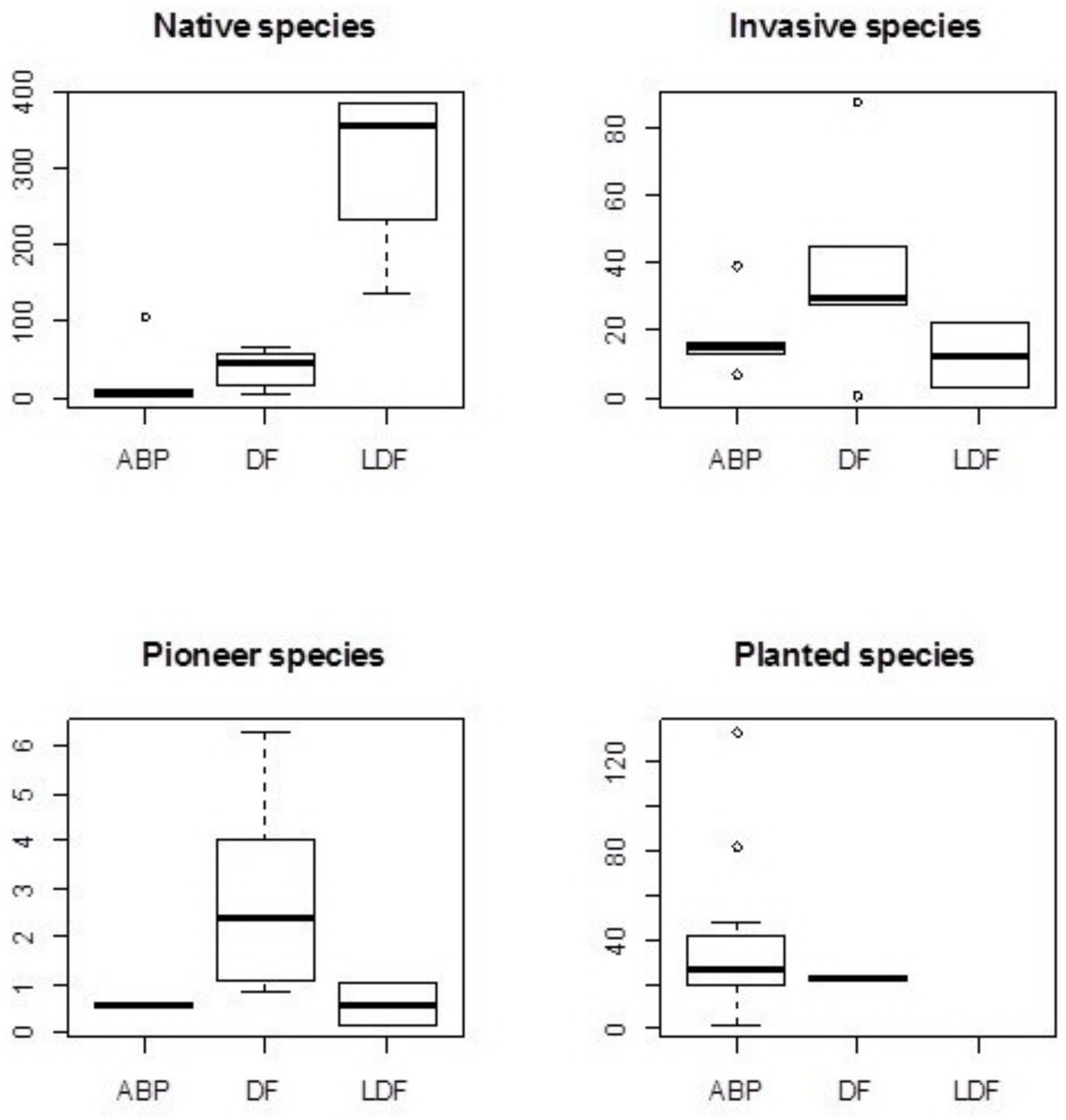

Fig. 4. Biomass (ton ha^{-1}) distribution among native, invasive, planted, and pioneer species at abandoned plantation (ABP), disturbed forest (DF), and less disturbed forest (LDF) in Halimun Salak corridor area.

that regeneration of native vegetation on degraded land in Singapore was blocked by invasion of fern *D. linearis*. This species in peninsular Malaysia can survive under shading area, forms dense thickets aggressively, expands the rhizomes and excretes the allelopathic compound thereby could prevent the establishment of tree regeneration (Shono *et al*., 2006; Nishimura, 2011). This fern combined with *I. cylindrica* which has a high efficiency nutrient uptake slow the decomposition rate of litters. This drought tolerant and fire resistant species can survive in unfavorable condition, thus inhibit succession and tree establishment in disturbed areas (Nishimura, 2011).

M. emenii as a fast growing tree now invades natural forest widely, especially in tropical areas. Binggeli & Hamilton (1993); Binggeli (2003) and Rinaldi *et al*. (2008) reported that this species has strategies as follow: first, its seeds are easily distributed by bird, as hornbill in Tanzania; second, seeds and seedlings can survive in longer period and they grow rapidly when light increase due to the establishment of gap; third, germination of seed is triggered by water thus the seed can easily germinate.

The invasion of quinine tree *C. pubescens* which categorized as 100 of the world worst invasive species (Richardson, 2008; Lowe *et al*., 2000) and small shrub *C. hirta* at this corridor area seems not serious, however monitoring to these species is needed to control the invasion rate. Though it invaded in limited area of corridor area, the existence of *C. pubescens* increased the risk of forest degradation because local people harvested the bark by cutting its stand for commercial use (Cahyadi, 2003).

Tree species in Halimun Salak National Park have potential as building material, fuel wood, board manufacture, edible fruit/vegetable, furniture and medical plants (Cahyadi, 2003; Gunawan *et al*., 2007; Polosakan, 2011). Though access to the remnant forest is difficult, local people enter the less degraded forest to explore timber trees such as *S. wallichii*, *A. excelsa,* Myrtaceae and Fagaceae due to economics needs (Polosakan 2011). Therefore, collaboration between local people and the manager of national park is required to conserve the corridor area.

Ecological value of corridor area

Rehabilitation of degraded forest becomes major concern in the corridor area, considering its functions to provide movement and foraging sites for endangered species, maintain water balance, support biodiversity and prevent soil and land slide (Gunawan *et al*., 2007; Rinaldi *et al*., 2008; GHSNPMP-JICA, 2009). Degradation and fragmentation at corridor affected population number of endangered animals (Van Ballen *et al*., 1999; Cahyadi, 2003; Dewi *et al*., 2007; Rinaldi *et al*., 2008; Yumarni *et al*., 2011). The javan gibbon needs forest canopy for their movement, but lack of emergent tree decreased their population within degraded area (Dewi *et al*., 2007; Yumarni *et al*., 2011). Ario (2007) reported that javan leopard can live close to human habitation, but they need broader habitat for foraging activity. Thus, the fragmentation will impact the leopard population. However, during the study, we only found leopard's footprints at less degraded area between Mt. Halimun and Mt. Salak. The importance of corridor is not only for conservation but also substantial for human because the rivers from this area can support some areas surrounding national park and prevent land slide during rainy season (Rinaldi *et al*., 2008; GHSNPMP-JICA, 2009). Therefore rehabilitation on degraded land is crucial to recover the function of corridor GHSNP.

Management strategy for forest rehabilitation

Local people living adjacent to national park seem not clearly understand about the function of corridor, thus exploitation was ongoing severely in this area. Moreover, low economic level of rural community lead to high utilization of forest area for agriculture, timber, fuel wood and medical treatment (Galudra, 2003; Rinaldi *et al*., 2008; Polosakan, 2011). Even though resource exploitation by human intervention is prohibited in national park area, it is hard to eliminate because they settled before the establishment of national park.

The proper strategy on forest rehabilitation must be well designated for better management in the future. The community based-conservation management system which considering local knowledge and sharing benefit related to conservation and utilization initiatives are thought to be the best way to maintain conservation area (Harada, 2003; Gunawan *et al*., 2007; Perbatakusuma *et al*., 2010). In addition, environmental education must be disseminated to local people thereby local people can contribute on this conservation program in same vision. Due to local people settlement, rehabilitation program must consider the alternative livelihood for them, which can reduce their dependence on forest. The utilization zone can be established for economic purpose of local community (Galudra, 2003).

The abandoned plantation and secondary forest are susceptible to invasive species. Therefore, selection of proper native species is essential for planting enrichment to minimize the spread of the invasive species (Richardson, 2008; Binggeli, 2001; Binggeli, 2003; Fukuda, 2010).

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