Diversity of plant species and the presence of Invasive Alien Species (IAS) in the Sub-Montane Forest at Pakenjeng Region, Southern Part of Garut, West Java

C Kusmana1,3 and I Suwandhi2
1 Department of Silviculture, Faculty of Forestry, IPB University, Kampus IPB Dramaga, Bogor 16880 Indonesia
2 School of Life Sciences and Technology, Institut Teknologi Bandung (ITB), Jalan Ganesha 10, Bandung 40132 Indonesia

E-mail: ckmangrove@gmail.com

Abstract. Plant species diversity is an important ecological characteristic, especially to observe the complexity of forest ecosystems. The research is carried out to elaborate on the species composition, species diversity and the forest structure, and to identify the presence of invasive alien species (IAS) in the sub-montane forests at the Pakenjeng region, the southern part of Garut, West Java. The vegetation survey method used was a stratified sampling technique with the transects and line plots as sampling units for inventoring the trees, forest regenerations, and ground cover. These data are further analyzed to obtain information on abundance, dominance, importance value index (IVI), species diversity and evenness. Based on the species composition, the forest formation was categorized as a primary sub-montane forest with high species diversity characterized by the presence of tree species such as Altingia excelsa, Lithocarpus sundaicus, Castanopsis spp. and Podocarpus spp. showing the curve of inversed-J for horizontal structure with A, B and C canopy layers. The species of Eupatorium inulifolium, Musa zebrina, Piper aduncum and Lantana camara are categorized as IAS.

Keywords: Invasive alien species (IAS), species diversity, southern part of Garut, sub-montane forest

1. Introduction
Ecosystems in mountainous regions are strongly influenced by typical physiography, resulting in a specific form of physiognomy which is more specific than in lowland areas. The altitude and slope of the land cause the formation of microclimates condition which is different from the tropical lowlands in general, especially climate factors. Each species lives in different habitats according to its physiological and biochemical characteristics [3,4]. Besides, the diversity of plant species is an important indicator to determine the ecological characteristics of a natural forest ecosystem, especially the forms of complexity and dynamics of forest ecosystems.

One of the regions which have the luxurious mountain forests is Garut in West Java. Actually, Garut Regency consists of several mountains including Mount Papandayan, Guntur, Cikuray,
Burangrang, and several small mountains. The forest in these mountains is generally still in the form of primary forest, and the others are secondary forests that are formerly fired and encroached.

Mountain rainforest ecosystems in West Java, including Garut Regency, contain many species of conifer (needle leaf trees) genus Dacrydium, Libecedrus, Phyllocladus, and Podocarpus. There are also broadleaf trees such as Altingia, Liothcarpus, Quercus, Castanopsis, Actinodaphne, Litsea, and Eugenia spp. Various research results show that in these mountain forests there are also many types of understory, epiphytes, and lianas.

Sub-montane primary forest in the southern region of Garut Regency including the Pakanjeng region is one of the storage for the diversity of plant species. Its current existence needs to be known earlier regarding the structure and composition of its species as well as the tendency for the emergence of the invasive alien species (IAS) for management considerations.

This study aims to determine the species composition, species diversity, and structures of sub-montane natural forests, and to identify the presence of invasive alien species (IAS) in those forests located at the Pakanjeng region on the southern part of Garut. This research is urgent because many parties have an interest in using the area for other purposes. The benefits of this research are to obtain up-to-date information on the species diversity, species composition, and stand structure as well as the presence of invasive species that can disrupt the development of open areas within the region. This research can also provide input for area managers in order to control invasive species earlier.

2. Method

The research has been conducted on sub-montane natural forest areas located in Garumukti Village, Pakanjeng District, Garut Regency, West Java, from February until April 2012. The research location has a type of wet climate with an average rainfall of 2,500-3,500 mm/year, the altitude ranges from 1000-1500 m above sea level, generally undulating hilly topography with slopes dominated by land with slope classes > 40%, and only a small portion is flat-sloping land (<15%).

The preliminary stage is carried out by analyzing the images and maps which are divided into three classes based on canopy cover characteristics interpreted using WorldView Panchromatic (WorldView-2) high-resolution satellite images as follows (figure 1):

- Low canopy cover forest (HJR): forests with low canopy cover are natural forest cover conditions with a percentage of canopy cover from dominant trees less than 40%. The dominant trees are trees in the A and B strata. Forest areas tend to be located on steep cliffs, dominated by natural tree species such as pasang and huru, also found various types of rattan and herbs. Trees and other plants tend to be dense with high natural regeneration.
- Medium canopy cover forest (HSD): Forests with medium canopy cover are natural forest cover conditions with the percentage of canopy cover from dominant trees ranging from 41% to 70%. It is a forest which is in the succession process towards a stable forest (climax).
- High canopy cover forest (HLB): Forests with high canopy cover are forests generally having a very tight percentage of canopy cover which is greater than 70%. Forests with this criterion are generally old natural forests which are heading towards climax.

![Figure 1. Classification of the research area based on canopy density using high-resolution satellite images WorldView Panchromatic [(a) HJR, (b) HSD, and (c) HLB].](image-url)
The next step is to make observations and measurements in the field. A vegetation analysis plot was made in each part of the forest by applying stratified systematic sampling techniques with sample units in the form of the transect. The stratification of vegetation is made based on the classification of forest cover conditions. In the observation areas transect of 20 m wide each with length based on field conditions was divided into subplots for analysis of tree and its regeneration (seedling, sapling, and pole) and other plant forms (understorey, epiphytes, lianas, and palms).

This study also identified types of invasive alien species (IAS) for finding out the distribution condition within the region and then described it based on the list of IAS types in Indonesia [1,2].

3. Results

3.1. Species composition

The results of the overall vegetation analysis in the research area, there are 75 species of trees (from all growth stages), 69 species of plants (including herbs and shrubs), 5 types of epiphytes (orchids and ferns), and 14 species of lianas (including rattan). The description of the species composition condition in each forest canopy cover type for each habitus and tree growth stage is presented in figure 2.

![Figure 2. Species composition of plants based on life form and tree growth stage in three class of forest canopy cover (Note: HLB: forest with high canopy cover; HSD: forest with moderate canopy cover; HJR: forest with low canopy cover).](image)

Based on the information on figure 2, it can be seen that forests with low canopy cover (HJR) have the highest tendency at the level of regeneration and understorey compared to HLB and HSD, while epiphytic and liana communities tend to have no difference. This condition is presumed because HJR still has quite a light canopy and open spaces, and it allows various types of regeneration and understorey to emerge. Furthermore, the species commonly found in each forest canopy cover class are presented in table 1.
The montane forest ecosystem is composed of types of mountain primary forests, including genera found in all areas and at all tree growth stages, namely Lithocarpus, Altingia, Castanopsis, Schima, Dacrycarpus, and Podocarpus. Based on IVI, there is no prominence in certain species, but at the tree level, it is found that Altingia excelsa has a sufficiently large IVI compared to others because of a large diameter size.

Forests in this region are morphologically composed of sub-montane forest climates typical of West Java (Fago-Lauraceous forest) [4,5]. Climax tree species which form the main form of the stand morphology of the sub-montane forest researched are Rasamala (Altingia excelsa), pasang (Lithocarpus sudaicus), puspa (Schima wallichii), tungurrut (Castanopsis tungurrut), kiputri (Podocarpus neriifolius), jamuju (Podocarpus imbricatus), saninten (Castanopsis argentea), pasang beunyeur (Cuerus lineata), and pasang jaranak (Castanopsis javanica). Besides many members of the Fagaceous family found in the area, various tree species are also found in the families of Lauraceae, Mirtaceae, Moraceae, Euphorbiaceae and others which are the basic flora for the sub-montane forests of West Java.

### Table 1. Common plant species found in three class of forest canopy cover

| Growth Level | HLB | HSD | HJR |
|--------------|-----|-----|-----|
| Seedling     |     |     |     |
| Lithocarpus sudaicus (10,7) | C. argentea (8,5) | S. wallichii (4,8) |
| Schima. wallichii (6,5) | C. tungurrut (16,5) | C. argentea (4,6) |
| Altingia. excelsa (4,5) | Dipterocarpus haseltii (6,1) | L. sudaicus (4,2) |
| L pseudomoluccus (3,5%) | Quercus gemeliflora (4,9) | C. javanica (4,5) |
| Castanopsis javanica (4,3) | L. sudaicus (5,1) | C. tungurrut (3,8) |
| Castanopsis acuminatissima (3,5) | A. excelsa (4,7) | L. pseudomoluccus (3,7) |
| Castanopsis sp. (2,6) | S. wallichii (3,0) | P. neriifolius (3,1) |
| Dipterocarpus haseltii (3,5) | A. excelsa (4,7) | Q. gemeliflora (2,9) |
| Podocarpus neriifolius (2,6) | S. wallichii (3,0) | A. excelsa (4,7) |
| C. tungurrut (2,6) | S. wallichii (3,0) | L. sudaicus (2,0) |
| Sapling       |     |     |     |
| L. sudaicus (16,3) | L. sudaicus (16,8) | L. sudaicus (8,9) |
| S. wallichii (8,2) | C. argentea (13,6) | S. wallichii (6,7) |
| C. tungurrut (5,7) | C. tungurrut (6,3) | C. argentea (3,2) |
| A. excelsa (4,1) | C. tungurrut (6,3) | C. argentea (3,2) |
| Pole          |     |     |     |
| L. sudaicus (15,4) | A. excelsa (17,2) | L. sudaicus (16,4) |
| A. excelsa (12,5) | L. sudaicus (13,5) | C. tungurrut (13,2) |
| S. wallichii (11,0) | C. tungurrut (11,2) | S. wallichii (12,5) |
| C. tungurrut (7,8) | C. argentea (10,7) | A. excelsa (10,7) |
| Podocarpus neriifolius (7,4) | S. wallichii (5,9) | C. argentea (9,5) |
| Dacrycarpus imbricatus (5,8) | S. wallichii (5,9) | Q. lineata (8,9) |
| Tree          |     |     |     |
| A. excelsa (40,6) | A. excelsa (33,8) | A. excelsa (34,1) |
| L. sudaicus (20,3) | L. sudaicus (15,9) | L. sudaicus (17,7) |
| S. wallichii (14,0) | C. tungurrut (13,7) | S. wallichii (12,7) |
| C. tungurrut (12,4) | C. argentea (8,7) | C. tungurrut (8,5) |
| P. neriifolius (6,6) | S. wallichii (8,3) | C. argentea (6,1) |
| D. imbricatus (6,3) | S. wallichii (8,3) | C. javanica (5,9) |
| C. javanica (4,3) | S. wallichii (8,3) | Q. lineata (5,5) |
| Note: numbers in parentheses indicate Important Value Index (IVI)
Several open areas at the research site were occupied by some pioneers such as *Mallotus peltatus*, *Glochidion molle*, *Engelhardia spicata*, and others. In addition, in relatively small proportions there are several types of exotic trees such as *Sengon* (*Albizia lophanta*), *Afrika* (*Maesopsis eminii*), *Nangka* (*Artocarpus heterophyllus*), *Mahogany* (*Swietenia mahagoni*), *Pine* (*Pinus merkusii*), *Petai* (*Parkia speciosa*), *Avocado* (*Persea americana*), *Muncang* (*Aleurites moluccana*), *Jengkol* (*Lithesellobium jiringa*), and *Suren* (*Toona sureni*), which grows adjacent to the forest boundary.

### 3.2. Abundance and dominance

The abundance conditions in each class of forest canopy cover tend to be the same, the seedling stage has a very large abundance (3600-4000 ind/ha), followed by a sapling, pole, and tree stages (figure 3). This abundance condition shows that the number of regeneration is generally very large, then decreases until lagging behind a few individuals at the tree stage. In general, the number of individuals per hectare is in abundant condition.

![Figure 3](image-url) Abundance of tree and its regeneration (ind ha⁻¹) in the three classes of forest canopy cover.

Basal area of the tree and its regeneration tend to be the same in the three classes of forest canopy cover (table 2). The observations in the field show that dominant trees such as *Altingia excelsa*, *Lithocarpus sundaeus*, and *Schima wallichii* generally have large stem diameters resulting in the large basal area.

Sub-montane forest in the Pakanjeng region on high canopy forest (HLB), medium canopy forest (HSD) and low canopy forest (HJR) have not so high tree densities (ranging from 28-32 trees ha⁻¹), but the basal area is relatively high ranging from 68,83-90,33 m² ha⁻¹.

### 3.3. Species diversity and evenness

All forest communities (HLB, HSD, and HJR) have high species diversity and evenness (figures 3 and 4).
Table 2. Abundance and basal area of trees and its regeneration in three classes of forest canopy cover.

| Growth stage | Abundance (ind ha$^{-1}$) | Basal area (m$^2$ ha$^{-1}$) |
|--------------|---------------------------|-----------------------------|
| HLB          |                           |                             |
| Seedling     | 3645                      | -                           |
| Sapling      | 630                       | -                           |
| Pole         | 102                       | 68.83                       |
| Tree         | 31                        | 84.78                       |
| HSD          |                           |                             |
| Seedling     | 3877                      | -                           |
| Sapling      | 663                       | -                           |
| Pole         | 110                       | 76.92                       |
| Tree         | 28                        | 88.73                       |
| HJR          |                           |                             |
| Seedling     | 3993                      | -                           |
| Sapling      | 484                       | -                           |
| Pole         | 112                       | 71.50                       |
| Tree         | 32                        | 90.33                       |

Based on figure 4, the forests with low canopy cover (HJR) have the highest level of species diversity, especially in seedling and sapling growth stages. Light intensity is thought to be a determining factor for this condition, namely, in HJR there are many gaps and open areas compared to HLB and HSD. The diversity of tree species and regeneration in this forest area is categorized as high ($H \geq 2.5$), with 72 species in HJR and 67 species in both HLB and HSD. Tropical mountain forests have high biodiversity, this is due to the scale of the mountain, various characteristics, orographic heterogeneity, and geological as well as edaphic conditions also have an important role in the plant community [6].

The pattern of plant dominance and animal species richness tends to be determined by changes in elevation gradient (altitude) [7]. The maximum richness levels found at medium altitude (especially between 500-2,000 m asl). It is probably caused by the support of climate variables such as temperature and humidity, energy availability and productivity of ecosystems, historical and evolutionary processes, and the extent of distribution.
Figure 5 shows that in the three forest communities, trees and it is regeneration there are fairly distributed. It means that both the number of species and individuals trees and it is regeneration tend to be proportional. There are no prominence dominant tree species.

![Figure 5. Evenness level of the tree and its regeneration at HLB, HSD, and HJR.](image)

The forest floors have a very diverse abundance of various species of understorey (around 46 species) which are generally in the form of herbs and shrubs. There were also many epiphytes (7 species) in the form of orchids (Orchidaceae), Asplenium, and lianas (mainly in the form of 10 species of rattan, enriched the high complexity of the plant community. Based on the composition of plant species and forest stand structure which is similar to the sub-montane forest climax typical of West Java (Faga-Lauraceous forest), the forest ecosystem in the research site categorized as a sub-montane forest climax.

3.4. Stand structure
The stand structure in all forest communities tends to have similarities both viewed horizontally based on the distribution of stem diameter and vertically based on the position of the trees in occupying the canopy stratum. The horizontal stand structure is indicated by the abundance of trees based on stem diameter classes. The results of the study show that the community horizontal structure of trees in this region tends to form the curve of inverted-J (figure 6). This kind of horizontal stand structure is usually the case in primary/climax natural forests, generally with a tree stand population of 10 cm up, mostly concentrated in the C canopy layer. Besides that, it is indicated that the stand population tends to be normal.

The vertical structure can be seen based on the distribution of trees in the stratum of tree canopy heights, namely: A stratum (tree height reaches> 30 m); B stratum (height 20-30 m); and C stratum (height 4-20 m). The result shows that the trees dominated the C stratum, while the A stratum was only occupied by a small number of trees, especially the species of Altingia excelsa, Lithocarpus sandaicus and Castanopsis tungurrut (figure 7).
3.5. Presence of invasive alien species (IAS)
Invasive alien species (IAS) are species originating from outside which also invade natural areas, then widely affecting habitat they invade. Those species, both native and non-native species, colonizing habitat massively. The effects of alien species on native species and ecosystems are numerous and usually irreversible. The impact is sometimes massive but often subtle. Natural barriers such as oceans, mountains, rivers, and deserts which allowed the intricate co-evolution of species and the development of unique ecosystems have been breached over the past five centuries, especially during
the twentieth century, by rapidly accelerating human trade and travel. Plane, ships, and other forms of modern transportations have allowed both intentional and unintentional movement of species between different parts of the globe resulting in unexpected and sometimes disastrous consequences [8].

The presence of invasive alien species (IAS) identification results using the Global Invasive Species Database (2012) and the BIOTROP List of Indonesian Invasive Alien Species [8] show that primary forest communities in the research area were found to be entirely understory such as herbs and shrubs, while at the tree level they are not identified. The results of the IAS identification in the research area are presented in table 3.

Tabel 3. IAS presence in three different forest community.

| No. | HLB | HSD          | HJR          |
|-----|-----|--------------|--------------|
| 1   | Eupatorium inulifolium | Chromolaena ordorata | Piper aduncum |
| 2   | Musa zebrina         | Musa acuminata.   | Chromolaena ordorata |
| 3   | Eupatorium riparium  |                          |               |
| 4   |                         | Lantana camara      |
| 5   |                         | Imperata cylindica  |

Identification source: [1,8]

Based on table 3, there are 7 species of IAS in total. There is a tendency for higher invasion rates in HJR from other forest communities characterized by a greater number of species. It is due to the presence of certain open areas. The presence of invasive species is generally found in open areas or gaps, especially in the forests with low canopy cover (HJR). Invasive species are found at the life forms of understory, including kirinyuh (Eupatorium inulifolium Kunth (L.) RM King), Chromolaena odorata, pisangkole (Musa zebrina van Houtte ex Planek), kiseureuh (Piper aduncum L.), and kiara (Lantana camara). Some research results explain, several conditions which affect the speed of a species invasion are: 1) the ability to reproduce asexually and sexually; 2) fast-growing; 3) high reproductivity; 4) high spreading ability; 5) elastic phenotype, capable of changing shape depending on the latest conditions around it; 6) tolerance to various environmental conditions; 7) relationship with humans; and 8) other invasions that have been successfully carried out.

The presence of this invasive species is thought to originate from the areas around the forest which are generally in the form of mixed gardens belonging to the community, Perhutani plantations and shrubs. The invasion of those IAS is still in the early stage, this is indicated by the number of native species grow in the area so that it can still be immediately controlled.

4. Conclusions

Forest ecosystem in Pakanjeng, Garut, West Java is a type of climax sub-montane forest characterized by the tree dominant species, namely Altingia excelsa, Lithocarpus sundaicus, Castanopsis spp., Quercus spp., dan Schima wallichii. The forest has a high species diversity, very high evenness, and horizontal stand structure forming the curve of inversed-J and vertically dominated by the C stratum. Open areas in some parts of this forest have been invaded by IAS including Eupatorium inulifolium, Chromolaena odorata, Musa zebrina, Piper aduncum, and Lantana camara. The invasion was supposed to come from gardens and shrubs around the area that had been invaded earlier by the IAS.

5. References

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