Ph.D. THESIS

Elucidation of factors affecting epiphytic orchid community in *Schima wallichii* (DC.) Korth. (Theaceae) trees in a montane forest in West Java, Indonesia

インドネシア共和国西ジャワ州の山地帯林におけるイジュ（ツバキ科）に着生するラン群集に影響を及ぼす要因の解明

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Abstract

Schima wallichii (DC.) Korth. (Theaceae) is one of the common mountain species native to Java Island which have role as host trees for epiphytic plants. To clarify the relation between epiphytic orchid diversity and *S. wallichii* tree as host, forty *S. wallichii* trees with diameter at breast height (DBH) more than 20 cm were chosen randomly and epiphytic orchids attached were counted and identified in a montane forest of Mt. Sanggara, West Java, Indonesia. Each epiphytic orchid grown point was divided according to the Johansson's method which divides a tree stratification into five different zones (Johansson 1974), which are numbered from zone 1 to zone 5. Johansson zone 1 was omitted from the analysis because of no orchid there.

In total of 39 epiphytic orchid species, 1,731 individuals, were identified from forty host trees at the study site. Based on the species richness of epiphytic orchid attached, *S. wallichii* trees could be considered as an important host. *S. wallichii* trees DBH showed a positive effect on epiphytic orchid abundance (p<0.01), species richness (p<0.05), and diversity (p<0.05). There was significant difference in orchid abundance and species richness between trunk (zone 2) and crown (zone 3, 4 and 5) while no significant difference in them within crown zones. Tree size (DBH) and the number of branches positively affected orchid abundance and species richness in a host tree. Orchids were correlated positively in number with other vascular epiphytic plants at mid-crown (zone 4) and outer-crown (zone 5). Density of surrounding trees affected the orchids abundance negatively. *S. wallichii* trees are essential to epiphytic orchid community because they develop many branches for epiphytic orchids to colonize. Preserving the large crowned *S. wallichii* with low density of surrounding trees is effective for conservation of epiphytic orchids.

This thesis explores internal and external factors by SWOT analysis to formulate management strategies for orchid conservation in montane forests in West Java. From the SWOT analysis, several strategies were proposed to optimize the strengths and opportunities for the purpose of overcoming the weaknesses and to avoid the threats. Consequently, the proposed strategies can be an alternative for stakeholder to manage this forest sustainably not only for local residents but also for the epiphytic orchid and their hosts.

1. General introduction of Thesis

General introduction of orchid of Indonesia

The orchid family is probably the largest in the plant kingdom, having about 750 different genera with at least 25,000 native species (Hew and Yong 2004). There are two major types of orchid species based on the habitat, epiphytic and terrestrial. Epiphytic orchids attach on host tree trunk for living. Meanwhile terrestrial orchids grow from inside the soil, humus or litter. Aerial roots of epiphytic orchids are often exposed and free hanging, or sometimes appressed to a supporting structure. Conversely, roots of terrestrial orchids are usually hidden in the soil (Hew and Yong 2004). Most epiphytic orchids possess a prominent, enlarged bulbous structure at the base of their leaves, termed a pseudobulb as shown in Figure 1.1 although many species do not possess it (Dressler 1981).

Orchid is one of economically valuable ornamental flower group. *Vanda*, *Aranda*, *Dendrobium* and *Oncidium* are examples of economically important genus of epiphytic orchid, while the various species and hybrids of *Cymbidium* and *Spathoglottis* are examples of important potted terrestrial orchid in the market (Hew and Yong 2004). According to Puspitaningtyas (2005), even though orchids are not heavily used for basic human needs in Indonesia, they are commonly cultivated as ornamental plants, thus awareness arises about their extinction due to the accelerating rate of destruction as their natural forest habitats.

Beside economic benefits, orchids also have important ecological benefits. Epiphytic orchids provide habitat for certain animals like termites and ants, and terrestrial orchids cover the forest floor to keep the humidity of soil. Orchids have important role in food chain and food web in forest ecosystem. Several insect species like aphids and beetles will bite and eat orchid leaves, suck the nectar, and provide honey drops for ant food.

Orchid also has important role in forest Nitrogen cycle. Anwar et al. (1994). Orchid attracts pollinators in two ways: rewards and deceits. Many orchids provide nectar as reward for insects, however many orchids also deceit the pollinator by masquerade their appearance to attract pollinators in many ways (Dressler 1981).

Indonesia is a country endowed with the high population and the richest natural resources within its archipelago of 17,000. It is the world's largest archipelago, stretching from east to west with a length of 5,200 km and a width of 1,870 km (Kuncoro 2013). Indonesia is home for about 5,000 orchid species out of 25,000 orchid species in the world, that widespread throughout the islands in the country and most of it are epiphytes (Gunadi 1986, Banks 2004). The diversity and abundance of orchids in Indonesia are especially relevant to tropical climatic conditions. One of Indonesian native orchid is *Phalaenopsis amabilis* (L.) Blume (moth orchid) that exhibits beautiful flowers in butterfly-shape, white color and long-lasting flowers. This flower has been designated as Indonesian national flower in the year 1991 (Semiarti 2002).

Orchids are economically valuable commodity in Indonesia. Wild orchids species are remarkable genetic resource for hybridization especially for several countries such as Brazil, Thailand and Indonesia. Hybrid orchids have remarkable export value as Indonesia's commodity. From 2003 until 2008, export value of orchid of Indonesia always exceeds 1 million US Dollars (Statistics Indonesia 2009). Most of the exported species are hybrid species. However, now consumers start to look for native orchid species. Beside as export commodity, orchid also has potency as ecotourism asset. For example, the famous orchid ecotourism is located in 'Danau Sentarum National Park', Papua (Prasetyo and Zulkifli 2009). In this location, tourist can enjoy the beauty of various kind of orchids in its habitat.

Epiphytes including orchids are considered as one of the most threatened plant groups because they depend on the availability of host tree and are strongly affected by microclimate (Hietz et al. 2006, Mondragon et al. 2015). Orchids as sessile organisms are susceptible to changes in organic content, availability of light, hydrology, mycorrhizal associations, pollinator behaviour and competition (Raventós et al. 2011).

Review of epiphytic orchid in West Java

Java Island has at least 731 species of orchids, 231 are endemic. This number still has possibility to increase because until now not all forest areas are investigated. In West Java there are 642 species of orchids (Comber 1990). West Java is the area with the highest orchid endemicity in Java Island with 248 endemic species compare with Central Java (16) and East Java (49) (Comber 1990). With this numerous species, studies about epiphytic orchid community in West Java is still limited (Comber 1990, Puspitaningtyas 2004). In Java island, orchids are found from lowland to montane forest. However, most orchid species are recorded in between 1,000-2,400 m.a.s.l (Comber 1990). Montane rain forests are especially rich in epiphytes, which contribute significantly to species diversity in these ecosystems (Gentry and Dodson 1987, Barthlott et al. 2001).

There are several problems threaten orchid sustainability in West Java, especially for epiphytic orchids. The habitat loss caused by forest conversion into plantation, farming, and settlement areas threats orchid population in Java. Based on data from Forest Watch Indonesia (2014) natural forest cover of Java Island in 2013 only left 675,000 ha from 1,002,000 ha in 2009. Beside natural forest, there are limited production forest (394,314 ha) and special function forest (1,562,733 ha). The massive forest conversion is occurring in West Java Province because it is the most populated province in Indonesia. Extractive and illegal hunting and collecting of native orchid species to fill in market also threaten the orchid sustainability (Puspitaningtyas 2005) despite many of orchid species in Indonesia are listed as Appendix I and Appendix II in CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora).

Based on the information above, study about epiphytic orchid ecology in West Java become important. The importance of epiphyte studies for biodiversity research has been emphasised by Porembski and Barthlott (2000). Better understanding about epiphytic orchids and tree as its habitat may lead to the better management strategies.

In this study, I elucidated factors that affected epiphytic community in a host tree species, *Schima wallichi*. *S. wallichii* was chosen as focal tree because this species is the dominant tree in the study site and the most preferable host tree for epiphytic orchid to attach (Fardhani 2015; Figure 1.2). *Schima wallichi* (DC.) Korth. is an ever-green tree native to warm temperate and tropical regions of southern and southeastern Asia. This species is found in Himalaya, East Asia, and Southeast Asia (Tuyama 1989) distributing in across subtropical and tropical zones from 5 to 3300 m in elevation (Bloembergen 1952). *S. wallichii* often grows gregariously in primary lowland to montane forest, but is particularly common in disturbed and secondary forests, scrub and grassland and even in areas inundated with brackish water (Orwa et al. 2009). Industrial forest plantations of this species are reported in Malaysia and in South Sumatra, Indonesia (ITTO 2019). *S. wallichii* has a wide range of uses. This species is traded as commercial timber, good source of firewood, the bark is used for dying and as a source of tannins and the flowers are used medicinally (Oldfield 2018).

Important host tree traits relate to many factors such as tree architecture (branching patterns, branch size, distribution, branching angles) and physical and chemical bark characteristics (stability, texture, water-holding capacity, chemistry), but also species-specific growth rate and maximum size as well as leaf phenology (Zotz 2016). *S. wallichii* grows up to 45 m in height; trunk cylindrical, branchless for up to 25 m, diameter up to 250 cm, with a steep buttress rarely up to 1.8 m high (Figure 1.3); bark surface ruggedly cracked into small, thick, angular pieces, red brown to dark grey (Orwa et al. 2009). Several authors mentioned *S. wallichii* as one of host trees for the epiphytic plants (Marsusi 2001, Puspitaningtyas 2007, Setyawan 2000) such as bryophytes, orchids, and ferns (Setyawan 2000). According to Atmaja and Pamuji (2009) *S. wallichii* is one of the most preferable host trees for epiphytic orchids in Mt. Merapi National Park because it has stable, hard, and rugose bark (Figure 1.4).

By definition, epiphytes including orchid are physically dependent on a host, which immediately suggest the important roles of host tree structure (Zotz 2016). These may include the effect of host tree size (Flores-Palacios and Garcia Franco 2006), crown (Nadkarni et al. 2001), branches (Nieder et al. 2001), and other factors that may also influence such as host tree topography and aspect (Nadkarni et al. 2001).

Epiphyte species would be affected by their host tree in abundance, because large host-tree presumably provides greater available surface area and longer duration for colonization of epiphyte (Migenis and Ackerman, 1993; Muñoz et al., 2003; Bergstrom and Carter, 2008). In addition, Taylor and Burns (2015) showed epiphyte species richness consistently scaled positively with host tree diameter. Previous studies show that branch size and inclination affect the number of epiphytes in a host tree (Garth 1964, Nieder et al. 2001, Rudolph et al. 1998). However, the effect of number of branches on epiphytic orchid community in a host tree still remains unclear. Number of host tree branches may influence the epiphytic orchid community because branches provide epiphytes with place to attach. Furthermore, epiphytic orchid species which habit in a host tree may show difference in its vertical distribution among the layers from trunk to crown. The crown offers its occupants a wide microclimatic and nutrient regime and this variety undoubtedly contributes to arboreal plant diversity including epiphytic orchids (Nadkarni et al. 2001). Thus, the difference of the depth of crown layers may also affect the epiphytic orchid communities that inhabit the crown in a host because crown depth is strongly and negatively related to light availability (Coble et al. 2014; Gower and Norman 1991).

Factor such as density of surrounding trees may also affect the orchid community in a host tree directly or indirectly. Surrounding trees may affect the target tree positively as shelter or negatively as competitor (Vacek and Leps 1996) and may affect the epiphytic orchid community in that target tree. Report from Tremblay (2008) suggests that population size of a rare species of orchid (*Lepanthes eltoroensis*) would be affected by the excess foliage growth of its host and surrounding trees. Other factor is the effect of slope and aspect (compass direction of the slope) where a host tree stands. Light condition that required by plants to grow is affected by abiotic factors such as latitude and topography, including slope and aspect. Both latitude and topography are the major abiotic factors influencing the intensity and the direction of sunlight (Lang et al. 2010).

Epiphytic orchids commonly share habitat with other vascular epiphytic plants. Because densities of vascular epiphytes are frequently very low (Zotz 2016), biotic interactions among vascular epiphytes are not primary important for growth and survival of epiphytes (Zotz and Hietz 2001). However, the effect of other vascular epiphytes on epiphytic orchid community is still important to understand because competition between them can determine species persistence of epiphytic orchid (Taylor and Burns 2015). By studying the relation between epiphytic orchids and other vascular epiphytes on a host tree, the competitive interaction between those epiphytic communities may be revealed. In this study, epiphytic orchid community in a host tree species and several factors affecting it are analysed.

Furthermore, as the problems threaten the wild orchids and its habitat sustainability, it is also important to create the proper strategies to manage the forest. SWOT analysis could be expected to serve as a proper tool to formulate strategic management planning for orchid conservation. SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis is an instrument for making strategic planning which diagnoses internal strengths and weaknesses of organisations and formulates the opportunities and threats of the environment (Rauch 2007). SWOT is a tool designed to be used in the preliminary stages of decision-making on the one hand and as a precursor to strategic management planning on the other (Srivastava et al. 2005).

In this study, epiphytic orchid community in a host tree species and several factors affecting it are analysed. In addition, this research also aimed to create the proper strategies as a plan to manage the forest in sustainable way for orchid species, surrounding villages, company, and the sustainability of the orchid community itself.

General purposes of the study

The purposes of this study are:

1. To study the diversity of epiphytic orchid in a host tree species in montane forest of West Java, Indonesia.
2. To understand the factors that affecting epiphytic orchid community in a host tree species in montane forest of West Java, Indonesia.

3. To provide management strategy for preservation of epiphytic orchid species in montane forest of West Java, Indonesia.

The information contains this study could provide useful information regarding diversity of epiphytic orchid in West Java, Indonesia. The information will be of interest to other scientists interested in the ecology and taxonomy of epiphytic orchid especially in tropical montane forest of Java Island and South East Asia. Moreover, the information may be also utilized by stakeholder to preserve the epiphytic orchid species and its habitat.

Operational definition

There are some terms that need to be defined in this study:

1. The definition of epiphytic orchid abundance is the number of epiphytic orchid individuals per species.
2. The definition of epiphytic orchid species richness is the number of epiphytic orchid species in a host tree.
3. The epiphytic orchid diversity defined as the number of species and abundance of each species of epiphytic orchid that live in a host tree. In this study, epiphytic orchid diversity was quantified with Shannon-Wiener index of diversity (*H*') (Odum, 1953).

Figures

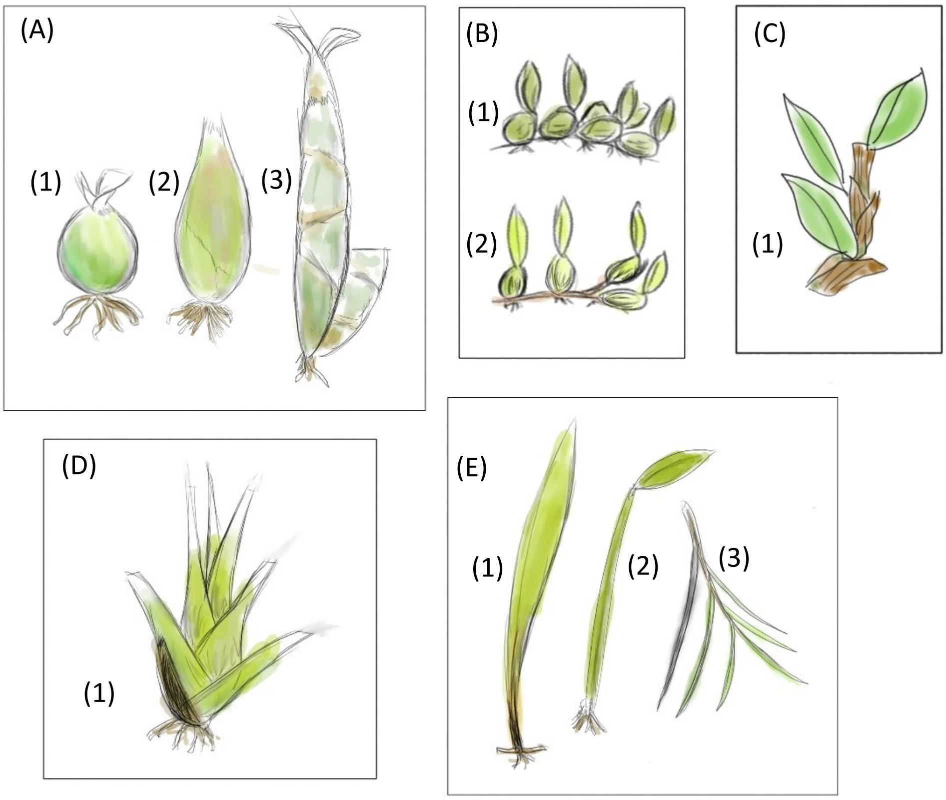

Figure 1.1 Various shape of pseudobulbs of epiphytic orchid with examples of the species in the study site.

(A) Visible pseudobulbs: (1) *Pholidota globossa*, (2) *Coelogyne miniata*, (3) *Eria flavescens.*
(B) Small but visible pseudobulbs: (1) *Bulbophyllum ovalivolium* (2) *Bulbophyllum tjadasmalangense.*
(C) Small and not visible pseudobulb: (1) *Bulbophyllum salaccense*
(D) Large but not visible pseudobulbs: (1) *Eria acuminata*
(E) No pseudobulbs: (1) *Bulbophyllum flavescens*, (2) *Ceratostylis capitata*, (3) *Schoenorchis juncifolia*

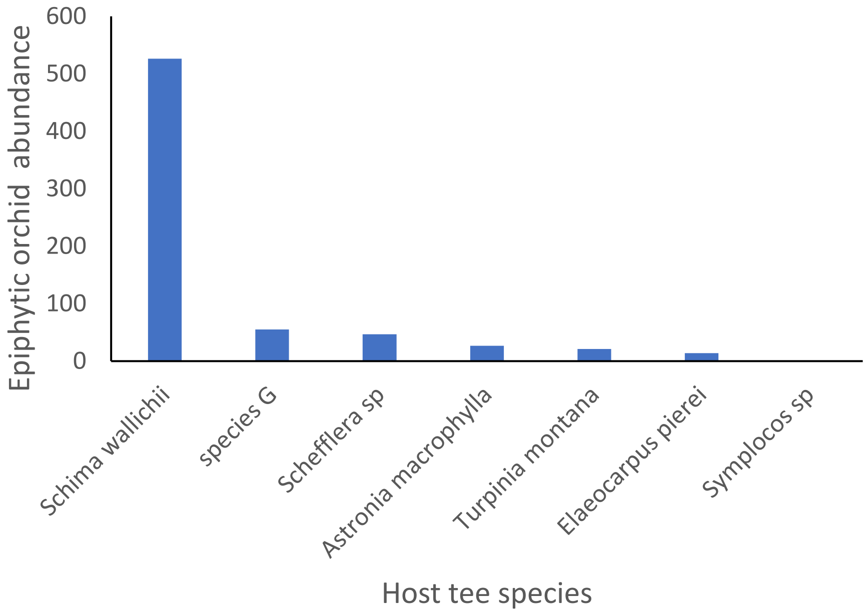

Figure 1.2 Orchid abundance in each species of host tree in 0.17 ha of study site area (Fardhani 2016).

Figure 1.3 Buttress of *S.wallichii* can reach up to 1.8 m.

Figure 1.4 Epiphytic orchids grown on rugose bark of *S.wallichii.*

2. **Epiphytic orchid diversity in *Schima wallichii* trees in a forest of Mount Sanggara, West Java, Indonesia**

Abstract

Schima wallichii is one of the forest tree species which grows in critical land and is widely used for forest restoration. To clarify the relation between epiphytic orchid diversity and *S. wallichii* population as host, forty *S. wallichii* trees with diameter at breast height (DBH) more than 20 cm were chosen randomly and the attached epiphytic orchid were identified in a forest of Mt. Sanggara, West Java Province, Indonesia. Diameter and height of each host tree was measured. Epiphytic orchids growing position on each host tree were grouped using Johansson's method into five different zones according to tree architecture. Total of 39 epiphytic orchid species were identified from whole host trees. The most abundant species were *Coelogyne miniata*, followed by *Bulbophyllum flavescens*, and *Eria multiflora*. The diversity of epiphytic orchid grown on *S. wallichii* trees was categorized as medium ($H' = 2.69$). Diameter of *S. wallichii* (DBH) showed a positive effect on epiphytic orchid abundance ($p<0.01$), species richness ($p<0.05$), and diversity ($p<0.05$). Conservation of *S. wallichii* will lead the sustainability of number, species richness, and diversity of epiphytic orchid in mountain forests of West Java.

Introduction

Epiphytes including orchids are considered as one of the most threatened plant groups because they depend on the availability of host tree and are strongly affected by microclimate (Hietz et al. 2006, Mondragon et al. 2015). Orchids as sessile organisms are susceptible to changes in organic content, availability of light, hydrology, mycorrhizal associations, pollinator behaviour and competition (Raventós et al. 2011).

Schima wallichii (DC.) Korth., a native in Java Island is one of the mountain species which grows in critical land and is widely used for forest restoration (van Steenis, 1972). Setyawan (2000) research at Mt. Lawu, East Java, showed that this species is mostly grown by bryophytes, orchids, and ferns. Several researches about epiphytic orchid and host tree including *S. wallichii* were performed in East Java (Marsusi 2001, Puspitaningtyas 2007, Setyawan 2000). From their observation, *S. wallichii* is not an 'orchid rich' host tree, in their study sites, each tree was attached by maximum two species of orchids.

Positive correlation between the occurrence of vascular epiphyte species and host tree size was reported (Andersohn 2004). Epiphyte species would be affected by their host tree in number, because large host-tree presumably provides greater available surface area and longer duration for colonization of epiphyte (Migenis and Ackerman 1993, Muñoz et al. 2003, Bergstrom and Carter 2008). Taylor and Burns (2015) showed epiphyte species richness consistently scaled positively with host tree diameter.

Epiphytes occurrence in a host tree can be grouped into several vertical zones according to Johansson (1974). The Johansson's zonation does not reflect height, distance above ground, and not characteristics of single branches, but tree structure. The zonation schemes have proven to be useful for standardized descriptions of epiphyte occurrence on host tree (Nieder and Zotz 1998).

Understanding of the relationship between host tree species and epiphytic orchid diversity may lead to better conservation strategy and management for orchid and its habitat. The purpose of this study was to clarify the epiphytic orchid diversity and species richness in *S. wallichii* population as host. The effects of host tree diameter and height and other vascular epiphytes dominancy on epiphytic orchid community were also revealed.

Method

Study area

The study area is located at Legok Jero area (6°48'41.47"S; 107°44'43.80"E) in Mt. Sanggara, West Bandung Regency, West Java Province, Indonesia (Figure 2.1). The average annual temperature there is between 19.7-28.0°C (StormGeo 2018). The altitude in this area is 1,724 m a.s.l. Based on previous study, total of 46 epiphytic orchids species were identified from various species of host trees at the study site (Fardhani et al. 2015). The crown layer was dominated by evergreen broad-leaved *S. wallichii* tree. This area is protected forest managed by a government-owned company in forestry in Indonesia. Most of this area was planted by coffee under the shade of large trees (Figure 2.2).

Data collection

Data collection was performed from at April 9th to 18th, 2017. Forty *S. wallichii* trees with diameter at breast height (DBH) more than 20 cm were chosen randomly for investigation (DBH; average 58.5 cm, maximum 107.3 cm, minimum 27.3 cm). Distance among each tree was minimum 20 meters.

Orchid abundance and species richness (number of species) were recorded using both single rope technique (Flores-Palacios and García-Franco 2006) and ground-based observation (Taylor and Burns 2015). Orchid grown point is divided according to Johansson's method (Johansson 1974) which divides a tree into five different zones. For finer observation, zone 2 was further divided into two parts: A and B (Figure 2.3) (ter Steege and Cornelissen 1989, Gradstein et al. 2003, Sanger and Kirkpatrick 2017). We omitted Johansson zone 1 from the analysis because there was no epiphytic orchid.

The clumped or creeping species were counted as one individual. Each orchid specimen was photographed or sampled for later identification using taxonomic literature (see Comber 1990). Diameter and height of host tree were recorded. In attempt to investigate the effect of other vascular epiphytes to orchid community, all vascular epiphytes numbers were recorded at each zone and grouped into four categories: dicot, monocot, fern, and orchid.

Data Analysis

Orchid diversity was measured using Shannon-Wiener index of diversity (*H*') (Odum, 1953). We measured the orchid diversity at each host tree and the diversity of orchid community at the study site. Data was calculated by the following formula

$H' = -\sum_{i=1}^{s}(pi \ln pi)$,

with categories:

$H' < 1.0$: low diversity, $1.0<H'<3.3$: medium diversity, $H' > 3.3$: high diversity,

where *H'* is the Shannon-Wiener index of diversity, *s* is the number of species in community, *pi* is the proportion of total abundance represented by i^{th} species.

We also analysed the orchid species richness and orchid abundance per height zone using Johansson method (Johansson 1974). Correlation analysis was performed between orchid and vascular epiphyte abundance. Regression analysis was also performed between DBH and orchid abundance, orchid diversity, and orchid species richness, and between Host height and orchid abundance, orchid diversity, and orchid species richness. All analysis was performed using R version 3.3.0 (R Development Core Team 2016) in RStudio Version 1.0.136 (RStudio Team 2016).

Results

Total 39 epiphytic orchid species were identified from forty host trees at the study site (Table 2.1). Among them, three species were endemic of Java Island. The diversity of epiphytic orchids grown on *S. wallichii* was categorized as medium (*H*'=2.69) at the study site. Several images of epiphytic orchid flowers blossomed in the study site were displayed in Figure 2.4.

Fern dominated the vascular epiphytes composition on zone 2A to zone 4 (Figure 2.5). The percentage of orchid increased on from zone 2A to zone 4 and became dominant on zone 5 (Figure 2.5). The most various vascular epiphytes were found on zone 2A. Monocot other than orchid was only found on zone 2A. Beside orchid, other monocot was consisted of grass, screw pine, and Aroids. The higher zone, the more dominant the orchid. From the field observation, when the zone 2A, 2B and 3 were dominated by epiphyte species other than orchid in some trees, epiphytic orchids were rarely found on those zones (Figure 2.6).

There was a positive correlation between orchids abundance and other vascular epiphytes (r=0.52, $p<0.001$) (Figure 2.8). Both orchid and other vascular epiphytes abundance tended to be higher with increase of tree diameter. Linear relationships between size of host tree (DBH) and abundance, species richness, and diversity of epiphytic orchid were shown (Table 2.2). There was a positive effect of host tree DBH on the epiphytic orchid abundance (p<0.01), species richness (p< 0.05), and diversity (p<0.05). Tree height did not have significant effect on orchid species richness and diversity (p>0.05), while positive effect of tree height on orchid abundance was shown (p<0.05).

Discussion

Total 39 of epiphytic orchid species grew on *Schima wallichii* trees at the study site among which three were endemic species of Java Island. Previous report showed that there were 46 of epiphytic orchid species at the study site with no regards to host species (Fardhani et al. 2015). Among 39 epiphytic orchids, six species were new records on *S. wallichii* trees. The species richness of orchid was higher than those of some previous reports from East Java, with only two species of orchid attached on this tree species from no more than three tree individuals observed (Setyawan 2000, Marsusi 2001, Puspitaningtyas 2007). Based on the orchid species richness on *S. wallichii* trees, this species could be considered as an important host for epiphytic orchid.

Vascular epiphytes are usually most abundant on mid-crown (Johansson zone 4) because the size of branches at this zone is thought to be suitable for epiphytes to attach (ter Steege and Cornelissen 1989, Nieder et al. 2001). In this study, Johansson zone 4 was also the most abundant and richest zone for epiphytic orchid, while zone 2A showed the least abundance. Branch inclination determines epiphyte abundance and inversely correlates to the epiphyte abundance (Rudolph et al. 1998). In contrast, Johansson zone 2A was the most diverse of vascular epiphytes because vascular epiphytes were composed of fern, dicots, orchid, and other monocots. Other monocots species were only found at zone 2A, most of which were screw pine and Aroids with large size and clump so that they will not reach higher zone.

Several micro environmental factors determined the vertical distribution of epiphytic plants including orchids in a host tree (Krömer et al. 2007). The light intensity and air temperature increase from ground level to the crown, while air humidity decreases (Parker 1995, Freiberg 1997, Krömer et al. 2007). Micro environmental factors are expected to be measured to understand whether they influence the epiphytic orchid distribution on *S. wallichii* trees.

At this study site, fern dominancy became decreasing along increasing height of each tree, while orchid became increasing. Other vascular epiphytes dominated the trunk (Figure 2.6) while orchids tend to grow at higher zone because they can adapt to the scarce resource (Figure 2.7). This condition is similar with studies at the mountain forest of Bolivian Andes (Krömer et al. 2007) and Guyana (ter Steege and Cornelissen 1989). At the study site, all orchids grown at crown were small and became dominant at crown layer and share habitat with lichens and small number of ferns. From our observation, most such orchids have succulent leaves, stem, and pseudobulb for water storage. Interaction and composition of epiphytes such as mosses and lichens might affect orchid to establish in a host tree.

Neither linear relationship between height of *S. wallichii* and epiphytic orchid species richness nor diversity were observed. In addition, the orchid species richness and diversity were not affected by host tree height. According to Andersohn (2004), height of host tree did not affect epiphyte diversity, while based on our finding, only plant height affected the abundance of epiphytic orchid positively. Relationships between epiphyte species richness and tree diameter (DBH) have been reported (Flores-Palacios and Garcia-Franco 2006, Taylor and Burns 2015). Epiphytes abundance also showed a positive relationship with tree diameter, a larger host tree would contain more number of epiphytes (Dunn 2000, Magalhães and Lopes 2015). This study also showed similar tendency with that, larger *S. wallichii* tend to host more orchid species and individuals.

Orchids tend to be restricted to larger host trees because of their preference for larger diameter supports (Zimmerman and Olmsted 1992). A larger host tree provided a greater available surface area for orchid to attach (Migenis and Ackerman 1993, Muñoz et al. 2003, Bergstrom and Carter 2008). With the thicker trunk, abundance, species richness, and diversity of orchid would tend to increase. Based on our study, larger and taller *S. wallichii* tree tended to host more abundance of orchids. However, other factors such as climatic condition and interaction with mycorrhiza may also affect the composition of the epiphytic orchid community (Dearnaley 2007, Krömer et al. 2007). This study can become a starting point for future investigation of the interaction between common evergreen tree *S. wallichii* as host and epiphytic orchid community.

Conclusion

This study revealed that forty *Schima wallichi* trees host as many as 39 species of epiphytic orchid at Legok Jero area, Mt. Sanggara, West Bandung Regency, West Java Province, Indonesia. The diversity of orchid on *S. wallichii* trees was categorized as medium (H'=2.69). The diameter of *S. wallichii* tree affected the epiphytic orchid abundance, species richness, and diversity, positively. The height of *S. wallichii* tree affected only the epiphytic orchid abundance positively. Conservation of *S. wallichii* trees will help the sustainability of the epiphytic orchid community in mountain forests of West Java.

Figures and Tables

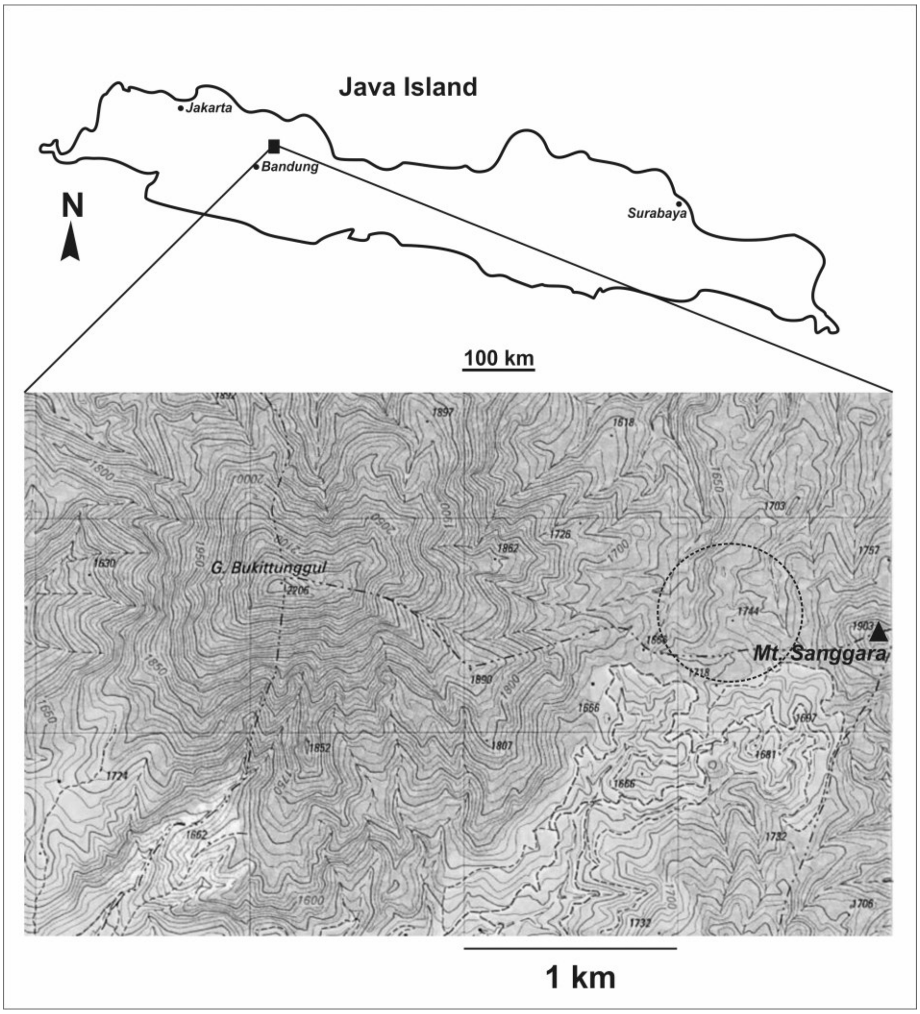

Figure 2.1 Map of study site (Google, 2018; Wikitravel, 2018).

Figure 2.2 Most of the forest floor was planted by coffee under the shade of tall trees.

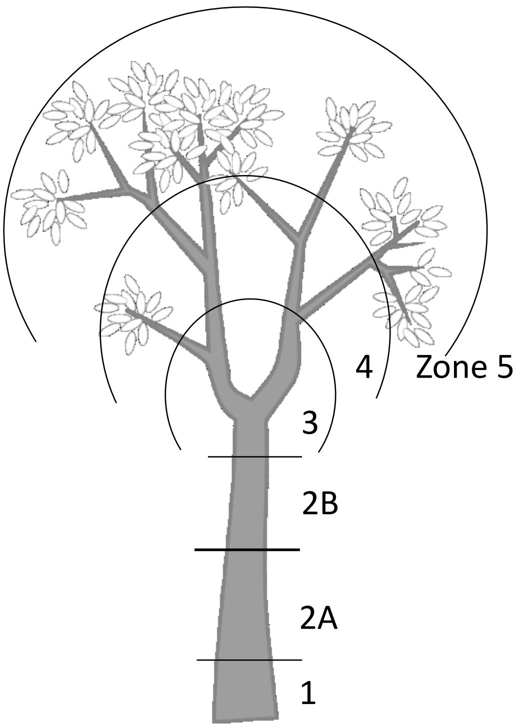

Figure 2.3 Illustration of the Johansson zones (zone 1: basal part of the trunk, zone 2A: lower trunk, zone 2B: upper trunk, zone 3: inner crown, zone 4: mid-crown, and zone 5: outer-crown) with modification after ter Steege and Cornellisen (1989).

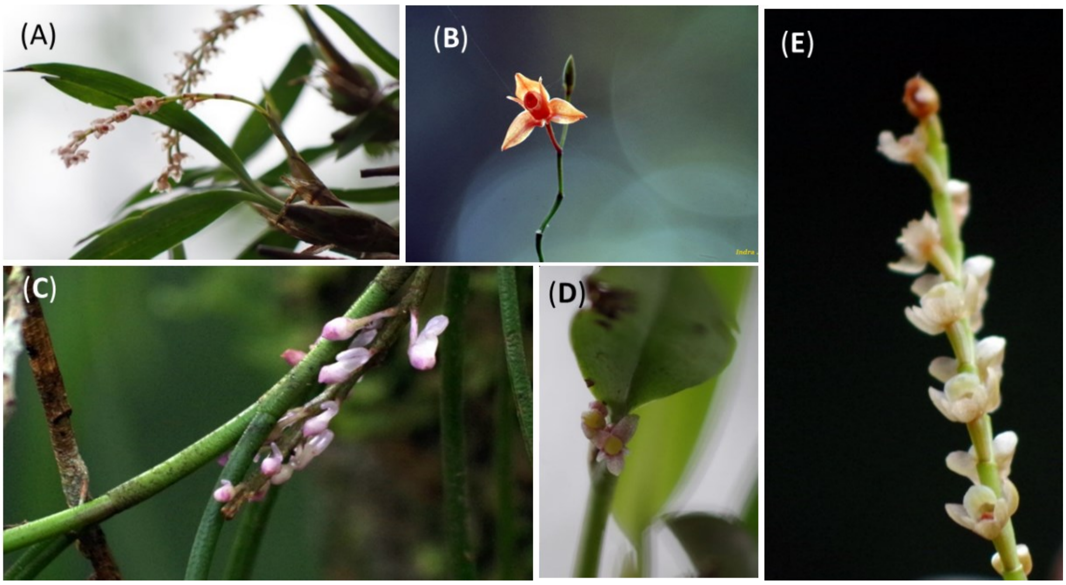

Figure 2.4 Epiphytic orchid flowers in the study site (A) *Pholidota carnea*, (B) *Coelogyne miniata*, (C) *Schoenorchis juncifolia*, (D) *Ceratostylis capitata*, (E) *Pholidota globossa*

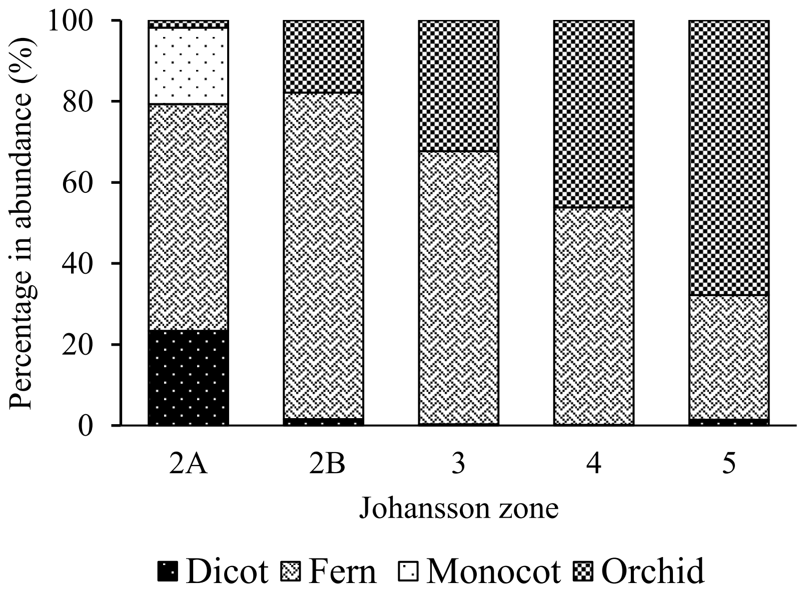

Figure 2.5 Composition of vascular epiphytic plant type at each zone of *S. wallichii* (2A: lower trunk, 2B: upper trunk, 3: inner crown, 4: mid-crown, and 5: outer crown).

Figure 2.6 Trunk of *S. wallichii* covered with epiphytic ferns and dicot.

Figure 2.7 Outer crown of *S. wallichii* covered with epiphytic orchid clumps.

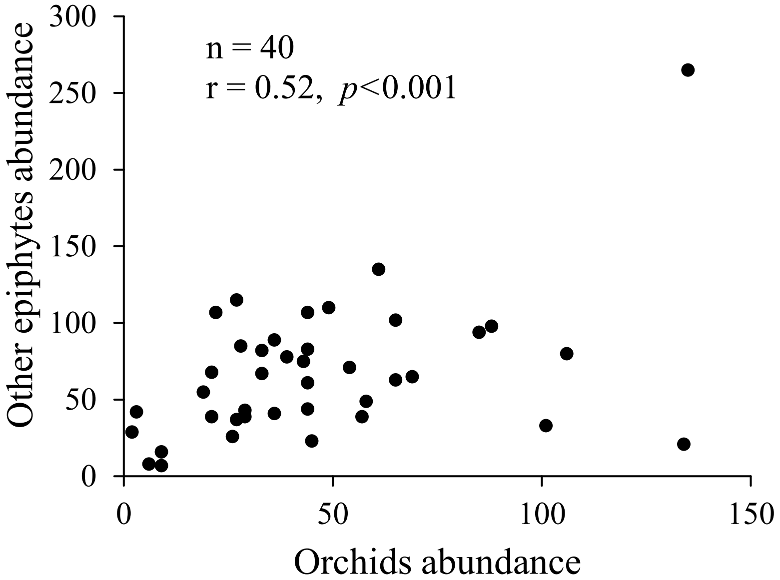

Figure 2.8 Correlation between other epiphytes abundance and orchids abundance.

Table 2.1 Species composition of epiphytic orchid on forty *S. wallichii* at Legok Jero area, Mt. Sanggara, West Bandung Regency, West Java Province, Indonesia.

No	Orchid species	Abundance	No	Species	Abundance
1	*Coelogyne miniata**	408	21	*Bulbophyllum absconditum*	10
2	*Bulbophyllum flavescens*	261	22	*Dendrobium heterocarpum*	9
3	*Eria multiflora*	201	23	*Oberonia padangensis*	9
4	*Pholidota globossa*	131	24	*Eria* spp.1.	7
5	*Pholidota carnea*	101	25	*Phreatia secunda*	7
6	*Schoenorchis juncifolia*	69	26	*Ceratostylis* spp.1.	6
7	*Ceratostylis backeri**	68	27	*Eria flavescens*	6
8	*Coelogyne trinervis*	59	28	*Eria lamonganensis*	6
9	*Dendrochilum cornutum*	54	29	*Flickingeria* spp.1.	6
10	*Trichotosia annulata*	51	30	*Liparis pallida*	6
11	*Dendrobium* spp.1.	48	31	*Bulbophyllum tjadasmalangense*	5
12	*Dendrochilum simile*	28	32	*Flickingeria* spp.2.	3
13	*Bulbophyllum salaccense*	27	33	*Oberonia* sp.	3
14	*Ceratostylis capitata**	26	34	*Bulbophyllum* spp.1.	1
15	*Bulbophyllum ovalifolium*	25	35	*Bulbophyllum* spp.2.	1
16	*Bulbophyllum stelis*	24	36	*Ceratostylis* spp.2.	1
17	*Appendicula angustifolia*	21	37	*Cleisostoma javanicum*	1
18	*Cheratochillus biglandulosus*	15	38	*Dendrobium* spp.2.	1
19	*Eria acuminata*	14	39	*Dendrobium* spp.3.	1
20	*Flickingeria angustifolia*	11		**Total**	1,731

*Java Island endemic species (see Comber, 1990).

Table 2.2 Slope for linear regression of epiphytic orchid abundance, species richness, and diversity against DBH and height of host tree.

	Orchid abundance			Species richness			Diversity		
	Slope	R^2		Slope	R^2		Slope	R^2	
DBH	0.72	0.23	**	0.06	0.15	*	0.01	0.15	*
Height	1.17	0.12	*	0.12	0.10	ns	0.02	0.09	ns

Significance: ***p*<0.01, **p*<0.05, ns not significant.

3. Epiphytic orchid vertical distribution in *Schima wallichii* trees in a montane forest of West Java, Indonesia

Abstract

Schima wallichii (DC.) Korth. is one of the mountain species native to Java Island which grows in critical land and is widely used for forest restoration. To clarify the vertical distribution of epiphytic orchid in *S. wallichii* trees and the correlation between epiphytic orchid and other vascular epiphytic plant in a host tree, forty *S. wallichii* trees with diameter at breast height (DBH) more than 20 cm were chosen randomly and the epiphytic orchid attached were identified in a montane forest of Mt. Sanggara, West Java, Indonesia. Diameter and height of each host tree were measured. Epiphytic orchids growing position on each host tree were divided into five zones using Johansson's method. In total of 39 epiphytic orchid species were identified from forty host trees in the study site. There were significant differences in orchid abundance and species richness between those on trunk and in crown. However, there was no significant difference in orchid abundance and species richness within crown zones. Tree size (DBH) and the number of branches positively affected orchid abundance and species richness in a host tree. Orchids and other epiphytic plants were correlated positively in number in mid-crown and outer-crown. *S. wallichii* trees are essential to epiphytic orchid community because they develop many branches for epiphytic orchids to colonize.

Introduction

Vascular epiphytes are a vital component of tropical biodiversity because they make up one-third to one half of total species richness in some tropical forests (Flores-Palacios and Garcia-Franco 2006). Of the 25000 species of orchids currently described, more than 70% are epiphytes (Gravendeel et al. 2004). The majority of studies on vascular epiphytes are from Central and South America (O'Malley 2009). Most of the previous studies concern about vascular epiphytes in general, whereas studies on epiphytic orchids are limited (Flores-Palacios and Garcia-Franco 2006, Krömer et al. 2007, Sanger and Kirkpatrik 2017, ter Steege and Cornelissen 1989, Zozt and Hietz 2001).

Epiphytic orchids depend on the availability of host tree and are strongly affected by microclimate (Hietz et al. 2006, Mondragon et al. 2015). Several authors have described species composition and richness of non-vascular (Sporn et al. 2009) and vascular epiphytes at different height stratifications in trees (Krömer et al. 2007, ter Steege and Cornelissen 1989). Zonal variation in the structural attributes of the host tree can influence the distribution of epiphytes because a host tree would provide various conditions in some microclimates (Sanger and Kirkpatrick 2017). That is, light, humidity, and temperature differ within the height of a tree (Sanger and Kirkpatrick 2015, Wagner et al. 2013). For example, the crown generally offers more light compared to dark understory for epiphytes (Nieder et al. 2001).

Several character of host trees will influence the orchid community. Previous studies show that branch size and inclination affect the number of epiphytes in a host tree (Garth 1964, Nieder et al. 2001, Rudolph et al. 1998). However, the effect of number of branches on epiphytic orchid community in a host tree still remains unclear. Number of host tree branches may influence the epiphytic orchid community because branches provide epiphytes with place to attach. In addition, tree size corelates positively with epiphytic richness (Flores-Palacios and Garcia Franco 2006, Taylor and Burns 2015). Furthermore, epiphytic orchid species which habit in a host tree may show difference in its vertical distribution among the layers from trunk to crown. The crown offers its occupants a wide microclimatic and nutrient regime and this variety undoubtedly contributes to arboreal plant diversity including epiphytic orchids (Nadkarni et al. 2001). Thus, the difference of the depth of crown layers may also affect the epiphytic orchid communities that inhabit the crown in a host because crown depth is strongly and negatively related to light availability (Coble et al. 2014; Gower and Norman 1991).

Epiphytic orchids commonly share habitat with other vascular epiphytic plants. Because densities of vascular epiphytes are frequently very low (Zotz 2016), biotic interactions among vascular epiphytes are not primary important for growth and survival of epiphytes (Zotz and Hietz 2001). However, the effect of other vascular epiphytes on epiphytic orchid community is still important to understand because competition between them can determine species persistence of epiphytic orchid (Taylor and Burns 2015). By studying the relation between epiphytic orchids and other vascular epiphytes on a host tree, the competitive interaction between those epiphytic communities may be revealed.

Schima wallichii (DC.) Korth. (Theaceae) is an evergreen tree species found across subtropical and tropical zones from 5 to 3300 m in elevation (Bloembergen 1952) distributing in Himalaya, East Asia, and Southeast Asia (Tuyama 1989). *S. wallichii* is one of the montane species native to Java Island which grows in critical land and is widely used for forest restoration (van Steenis 1972) because it grows rapidly after planting and shows fire-tolerance (Kamei et al. 2015). *S. wallichii* is common and dominant tree species in several tropical montane forests of West Java Province such as Mt. Gede, Mt.

Pangrango and Mt. Sanggara (Fardhani et al. 2015, Muhamad et al. 2014, van Steenis 1972, Yamada 1975). This species grows up to 45 m in height; trunk cylindrical, diameter up to 250 cm, with a steep buttress rarely up to 1.8 m high; bark surface ruggedly cracked into small, thick, angular pieces (Orwa et al. 2009). Several authors mentioned *S. wallichii* as one of host trees for the epiphytic plants (Marsusi et al. 2001, Puspitaningtyas 2007, Setyawan, 2000) such as bryophytes, orchids, and ferns (Setyawan 2000).

Differences in epiphyte microsites (in a host tree) exist at different spatial scales including within a single branch; among branches at different height of the tree; and among trees of different architecture (Nadkarni et al. 2001). Therefore, we propose that factors such as host tree size, number of branches, and crown depth of a host tree, density of trees surrounded host trees, host tree topography and the existence of other vascular epiphytes in the same host may influence the epiphytic orchid community in *S. wallichii* trees. We tested the following hypotheses: (i) there were differences in epiphytic orchid abundance (number of individual) and species richness (number of species) among different height stratifications of host trees, (ii) epiphytic orchid abundance, species richness, and diversity would be positively affected by the tree size, number of branches, crown depth of a host and (iii) there were competition between epiphytic orchid and other vascular epiphytic plant abundance within the same height layer of a host tree.

Method

Study site

The study site is located at Legok Jero area (6°48'41S; 107°44'43E) in Mt. Sanggara (1903 m a.s.l), West Bandung Regency, West Java Province, Indonesia (Figure 2.1). The altitude at the study site is between 1656 m to 1724 m a.s.l. Annual rainfall is 3047 mm and average annual temperature is 20.0^{o}C at Lembang which stand about 20 km from the study site (id.climate-data.org 2018). The forest was dominated with evergreen broad-leaved *S. wallichii* tree along with *Sloanea sigun, Schefflera rugosa,* and *Castanopsis acuminatissima*. The area belongs to a protected forest managed by a government-owned company of forestry. Large part of the forest floor had been cleared for coffee plantation under the shade of large trees (Fardhani et al. 2015).

Vertical distribution of epiphytic orchid

We selected forty *S. wallichii* trees randomly with diameter at breast height (DBH) more than 20 cm for investigation (DBH; average 58.5 cm, maximum 107.3 cm, minimum 27.3 cm). Each host tree was selected so as distance to the nearest *S. wallichii* tree was over 20 m.

Number of epiphytic orchid individuals and species grown on the host trees were recorded using both ground-based observation (Taylor and Burns 2015) and single rope technique (Flores-Palacios and Garcia-Franco 2006). Both methods are used because we can estimate the epiphytes presence with single rope technique more accurately although we can do that with the ground-based observation safer and faster (Flores-Palacios and Garcia Franco 2001).

In attempt to observe the vertical distribution, epiphytes orchid occurrence in a host tree were grouped into several vertical zones according to Johansson (1974). Each epiphytic orchid grown point was divided according to the Johansson's method (Johansson 1974) which divides a tree stratification into five different zones, which are numbered from zone 1 to zone 5. We further divided zone 2 into two parts: 2A and 2B (Figure 3.1) for finer observation (Gradstein et al. 2003, Sanger and Kirkpatrick 2017, ter Steege and

Cornelissen 1989). Johansson zone 1 was omitted from the analysis because no epiphytic orchid was found there. Each orchid specimen was photographed or sampled for later identification using taxonomic literature by Comber (1990). The clumped or creeping plant were counted as one individual.

Diameter and height of each host tree were measured with diameter tape and Haglof® Vertex III. Number of branches at each zone of each host tree was also counted (Number of branches; average 146, maximum 252, minimum 36). The minimum diameter of branches that included in the analysis was no less than 1 cm. Twigs with diameter more than 1 cm were considered as branch and counted. Crown depth of Johansson zone 3, 4, and 5 were also measured. The term 'crown depth' in this research is referred to the highest point of each Johansson zone 3, 4 and 5 (crown zone) from the ground (Coble et al. 2014). For example, the crown depth of zone 3 is the distance between its highest point and that of zone 2 (Figure 3.1). Numbers of all other vascular epiphytes (fern, monocot, and dicot) were also counted in each zone to investigate the effect of other vascular epiphytes on the orchid community. Data were collected from April 9th to 18th, 2017.

Analysis of data

To analyse the difference between observed and expected abundance of each epiphytic orchid species in each zone, Chi-squared test was conducted for species with more than 20 individuals. Scheffe's multiple comparison was conducted to test the difference in orchid abundance, species richness, and diversity among each Johansson zone. Generalised linear model (GLM) was constructed to determine which factors affect epiphytic orchid abundance and species richness. Explanatory variables are DBH, number of branches in crown zones (zone 3, 4, and 5) and crown depth of host tree. GLM with a

Poisson error distribution and a logarithmic link function is used for abundance and species richness since the factor generally satisfies the Poisson error distribution as a count variable (Bolker et al. 2009, Kwon et al. 2018). While for epiphytic orchid diversity in crown, GLM with Gamma error distribution with an inverse link function is used as the data was highly skewed (Cayuela et al. 2006, Crawler 2002, Everwand et al. 2014). Models would be ranked and selected from the lowest value of AIC (Akaike's Information Criterion). To avoid multicollinearity, we screened covariates with Variable Inflation Factor (VIF) and removed the variable with VIF>5 for moderate multicollinearity (Bagheri and Midi 2009, Mansfield and Helms 1982).

To understand the interaction between communities, Pearson's correlation coefficients were calculated between orchid and vascular epiphyte abundance in each zone. All of the statistical analyses were performed using R version 3.3.0 (R Development Core Team 2016) in RStudio Version 1.0.136 (RStudio Team 2016).

Result

Epiphytic orchid vertical distribution

Only three among forty *S. wallichii* trees were attached by orchids in zone 2A, therefore the division of zone 2A and 2B was not necessary in this study and then the result for these zones were combined as zone 2. In total of 39 epiphytic orchid species were identified from forty host trees (Table 3.1). Among them, three species *Coelogyne miniata, Ceratostylis backeri,* and *Ceratostylis capitata* were endemic to Java Island. Only two species of *Coelogyne miniata* and *Bulbophyllum sallacense* were found in every Johansson zone. Based on species accumulation curve (Figure 3.2), the number of host trees sampled was representative to describe the species richness of epiphytic orchid in the study site. In order to analyse the pattern of distribution, species with more than 20 individuals were used for analysis (Table 3.1). Among 17 species analysed, only four species had similar distribution with the total abundance. Sixteen out of 17 species inhabited every layer of crown zone (zone 3, 4, and 5). Five species (*S. juncifolia, B sallaccense, C. capitata, B. ovalivolium,* and *A. angustifolia*) grew on trunk significantly more abundant than the expected number. On the other hand, four species (*P. globossa, P. carnea, C. backeri,* and *D. cornutum*) grew on outer-crown (zone 5) significantly more abundant than the expected number (Table 3.1).

To compare the average abundance and species richness of epiphytic orchid among each (Johansson) zone, only host trees which were attached with more than 25 epiphytic orchid individuals were used for analysis (Figure 3.3). There were significant differences in orchid abundance and species richness between trunk zone (zone 2) and crown zones (zone 3, 4, and 5) (Figure 3.3). Crown zone consisted of more species and individuals of epiphytic orchid than the trunk zone did. However, there was no significant difference in orchid abundance and species richness among crown zones (Figure 3.3). Although it was not the richest species zone, Johansson zone 3 of *S. wallichii* trees in the study site had the most number of presence epiphytic orchid species while zone 2 had the least presence of epiphytic orchid species (Figure 3.4).

Factors affecting epiphytic orchid abundance, species richness, and diversity

GLM analysis of factors that affect orchid abundance and species richness was conducted for whole crown with no separation to each Johansson zone (zone 3, 4, and 5) because there was no significant difference in orchid abundance and species richness among those zones (Figure 3.3). No multicollinearity between explanatory variables was found (VIF

< 5) indicating no correlation among factors so that all variables can be included in GLMs. Five models for orchid abundance with lowest value of AIC were shown in Table 3.2. Among them, four models suggested the significant positive effect of host tree DBH on orchid abundance. Three models suggested the significant positive effect of number of branches on orchid abundance. Crown depth had significant positive effect on orchid abundance in some models. Some models suggested negative effect of crown depth on orchid abundance, although it was not statistically significant.

For orchid species richness, five models with lowest value of AIC were shown in Table 3.3. Two models suggested the significant positive effect of host tree DBH and number of branches on the species richness. Two models suggested positive effect of crown depth on orchid species richness, although it was not significant. Based on this result, crown depth did not significantly affect epiphytic orchid species richness. For orchid diversity, five models were shown in Table 3.4. All factors showed no significant effect on diversity of epiphytic orchid in crown. Therefore, orchid diversity in the crown was not significantly affected by all factors.

No correlation between number of orchids and other vascular epiphytes was found in zone 2 (Figure 3.5A) and zone 3 (Figure 3.5B). Only small number of orchids grew in most trees of zone 2 where many of other vascular epiphytes were found. In contrast, positive correlation between the number of epiphytic orchids and other vascular epiphytes was found in zone 4 (r = 0.38, $p = 0.017$, Figure 3.5C) and zone 5 (r = 0.55, $p < 0.001$, Figure 3.5D).

Discussion

The distribution tendency of orchid individuals in *Schima wallichii* tree was different among species (Table 3.1). In detail, some species such as *P. globossa, C. trinervis,* and *D. cornutum* distributed only in the crown, while some others inhabited both on the trunk and in the crown (Table 3.1). Among vascular epiphytes, habitat specialization occurs (Krömer et al. 2007). A study in the Bolivian Andes shows that between 50 – 80% of vascular epiphytes occur in most height zones and very few epiphytes are limited to one zone (Krömer et al. 2007). Similar phenomenon was observed in epiphytic orchids which inhabit *S. wallichii* trees in this study. We could understand that most of epiphytic orchid species do not colonize certain zone of *S. wallichii* tree but distribute in most zones, mostly in the crown.

Based on several researches, mid-crown zone (Johansson zone 4) contain the highest abundance and species richness of vascular epiphytes (Nieder et al. 2001, ter Steege and Cornelissen 1989). Orchids also tend to colonize the mid-crown zone of host where microclimatic conditions and host characteristics are probably most favourable for their survival in a tropical dry forest (de la Rosa-Manzano et al. 2014). However, in this study, such phenomena were not observed. Such that differences in both orchid abundance and species richness among three zones in crown were not significant (Figure 3.3). Therefore, all crown zones of *S. wallichii* tree can be presumably has similar microclimatic condition for epiphytic orchids inhabiting this tree species in a tropical montane forest of West Java. Orchids can adapt to the scarce resource condition of the higher zone of host tree (Krömer et al. 2007, ter Steege and Cornelissen 1989) and obtain the nutrient from stemflow and decaying detritus (Awasthi et al. 1995). We observed that most of the epiphytic orchid species growing on outer-crown had visible pseudobulb such as *C. miniata, P. globossa,* *P. carnea*, and *D. cornutum* or succulent leaves and stem for water storage such as *C. backeri*. On the other hand, epiphytic orchid grown on trunk had small pseudobulb such as *B. salaccense* and *B. ovalifolium* or had small sized stem without pseudobulb such as *A. angustifolia* to make it relatively easier to attach on vertical trunk (Table 3.1). Another reason why epiphytic orchid grown on trunk has smaller pseudobulb was that large pseudobulb to store water was not needed because it might receive nutrient and stemflow more than orchids grown on outer-crown do. However, there is no previous report about the size difference between epiphytic orchids grown on trunk and in crown although epiphytes are generally smaller than closely related terrestrial species (Zotz 2016). Beside water and nutrients, the host tree also has many different microclimates that may affect the distribution of epiphytic orchids (Sanger and Kirkpatrick 2017). Light and humidity condition may limit the epiphytic orchid abundance on cylindrical and branchless trunk of *S. wallichii* tree. Light varies dramatically from the outer branches of an emergent host tree to the dark shady base of the trunk (Sanger and Kirkpatrick 2015). Similarly, humidity and temperature also differ within the height of the host tree (Sanger and Kirkpatrick 2017, Wagner et al. 2013).

The tree size (DBH) and the number of branches in the crown had positive effect on the abundance (Table 3.2) and species richness (Table 3.3) of epiphytic orchids in *S. wallichii* trees. However, tree size did not significantly affect the epiphytic orchid diversity in crown layer (Table 3.4). Therefore, a host tree with larger size and greater number of branches would host more orchid individuals and more orchid species. Host tree size is one of the main factors influencing vascular epiphytes richness (Hirata et al. 2008). Epiphytes richness will depend on tree size because it determines the number of vertical microhabitats inside the crown (Flores-Palacios and Garcia-Franco 2006). Larger diameter trees will accumulate epiphytic species faster than smaller trees, once the first epiphyte have established (Taylor and Burns 2015). Because epiphytes including orchids tend to accumulate in larger and older host trees, in general, the diversity and abundance of epiphytes are therefore positively correlated to the successional stage of a forest (Nieder et al. 2001). Similar phenomena were observed in the study site. Larger *S. wallichii* trees showed tendency to host more abundant and various epiphytic orchid species compared with the smaller one. Conservation of *S. wallichii* tree with large size would lead to the conservation of various species of epiphytic orchids in the tropical montane forest of West Java.

Number of host tree branches in crown zones had positive effect on epiphytic orchid abundance (Table 3.2). This result added new insight to the previous studies about the effect of branches of the host tree on vascular epiphytes abundance. Based on the study by Nieder et al. (2001) branch size determines epiphytic plants abundance. Trees lacking of large diameter branches due to their branching pattern is considered as poor hosts for epiphytes (Garth 1964). Beside the size, branch inclination inversely correlates to the number of epiphyte individuals including orchid (Rudolph et al. 1998). Horizontal branches support epiphyte communities because they allow the accumulation of crown soil as a critical water source (Enloe et al. 2006, Nadkarni and Matelson 1991, Taylor and Burns 2015). From our observation in the study site, emergent *S. wallichii* trees had almost branchless tall cylindrical trunk up to about 20 meters height and had dense crown with numerous branches (146 in average). We observed that many branches inclined almost horizontally which would make epiphytic orchids easier to attach and colonize. Thus, based on this research, it was clarified that along with the branch size and inclination, epiphytic orchid abundance would also be affected by the number of branches in a host tree.

Both orchid species richness and diversity was not affected by crown depth (zone 3, 4, and 5) (Table 3.3 and Table 3.4). Based on Nieder and Zotz (1998), the Johansson's zonation does not reflect height and then, each host tree may have different zone height according to its structure. In the study site, short-crowned tree could host orchid species just as many as the long-crowned tree if that tree had numerous branches. For orchid abundance, only one model suggested the significant positive effect of crown depth (zone 3, 4, and 5) (Table 3.2). Crown depth didn't show significant effect on orchid species richness because from our observation, in the crown zones, most epiphytic orchid species spread their roots on comparatively horizontal branches rather than on more vertical branches. Only certain species of orchids such as *C. miniata* and *B. flavescens* were able to attach on more vertical branches in crown of *S. wallichii* trees because those species grew in colony, often attached on above of other epiphyte clumps and their rhizomes hugged the host branch.

Only small number of orchids grew in zone 2, while that zone was dominated by other vascular epiphytes (Figure 3.5A). Low number of orchids attachment to the trunk would be caused by the limited space and fewer branches for orchid to colonize. Rough bark of *S. wallichii* did not make orchid easier to attach. According to Vergara-Torres et al. (2010) bark characteristics such that bark thickness, texture and peeling behaviour do not correlate with host quality. Vertical branchless trunk made epiphytic orchids difficult to grow in the trunk zones of *S. wallichii* trees in spite of its quite rough bark. On the other hand, other vascular epiphytic plants, mainly fern, could grow on the trunk of *S. wallichii* trees. There was a positive correlation between abundance of orchid and other vascular epiphytes in zone 4 (Figure 3.5C) and zone 5 (Figure 3.5D). Ecological theory predicts that plants in stressful environments will show more positive than negative interactions between them (Bertness and Callaway 1994, Zotz 2016). In the crown layer, orchids share habitat with mosses, lichens and ferns and often clumped on the same location (Figure 3.6). This would imply that there would not be serious competition for space and nutrient between orchids and other vascular epiphytes in the middle and outer-crown.

Conclusion

Forty *Schima wallichi* trees host as many as 39 species and 1731 of epiphytic orchid in the study site. The number of orchid individuals and species were not significantly different among three crown zones. However, epiphytic orchids were more abundant in the crown zones than in the trunk zone. Host tree size and number of branches had positive effect on orchid abundance and species richness. Orchids and other epiphytic plants were correlated positively in number in mid-crown and outer-crown. Crown of *S. wallichii* trees are essential to epiphytic orchid community because it has numerous branches for orchids to attach. Preservation of *S. wallichii* trees with large size and numerous branches may also lead to conserving various species of epiphytic orchids in the study site and other tropical montane forests of West Java in general.

Figures and Tables

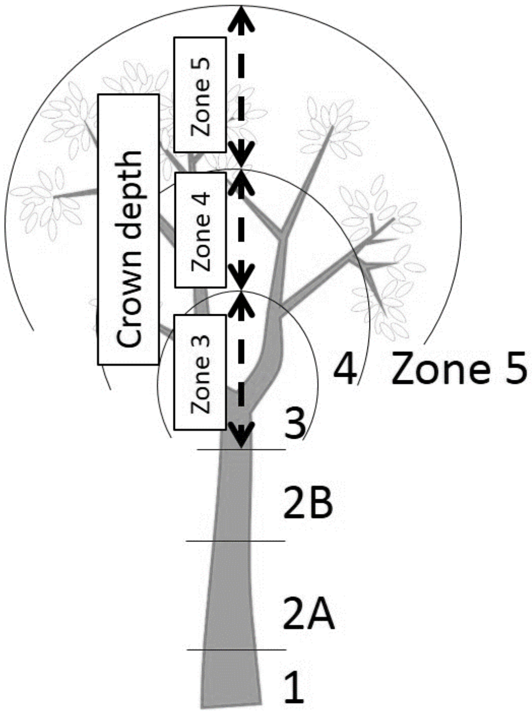

Figure 3.1 Illustration of the Johansson zones (zone 1: basal part of the trunk, zone 2A: lower trunk, zone 2B: upper trunk, zone 3: inner crown, zone 4: mid-crown, and zone 5: outer-crown) with modification after ter Steege and Cornellisen (1989), and crown depth of zone 3, zone 4 and zone 5.

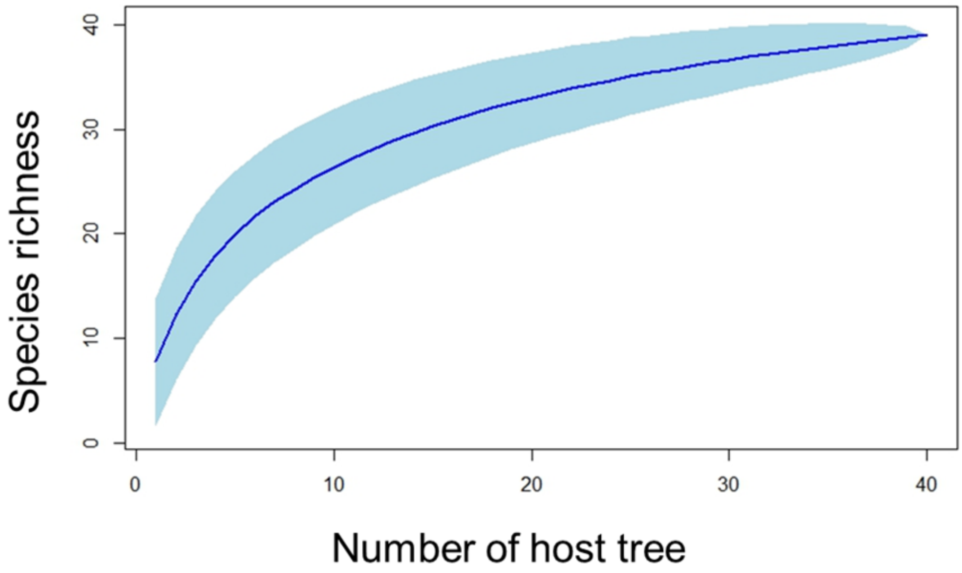

Figure 3.2 Species accumulation curve of epiphytic orchids in 40 host trees of *S. wallichii*. The shaded area represents the confidence intervals

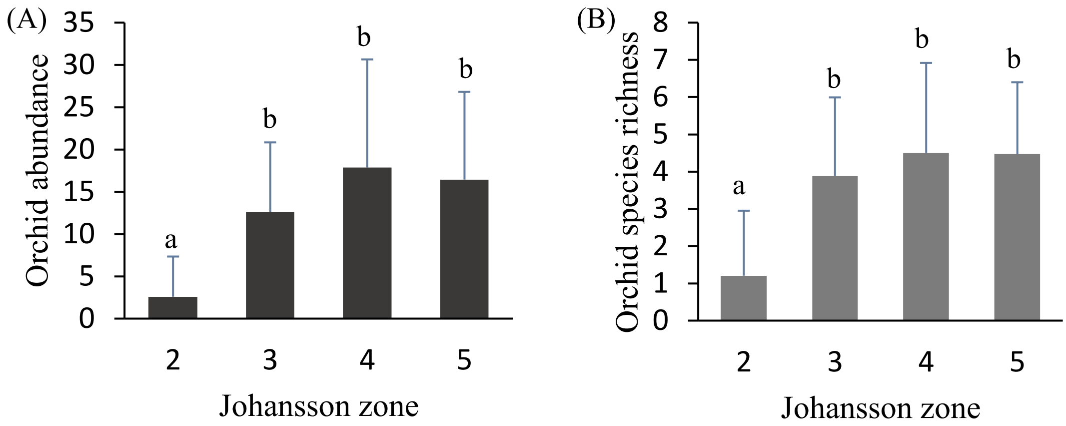

Figure 3.3 (A) Average abundance and (B) species richness of epiphytic orchid in each zone of *S. wallichii* trees in which more than 25 individuals of epiphytic orchid attached. n: 34. Different alphabets show significant difference in the average value among the Johansson zones (Scheffe's test, $p < 0.05$).

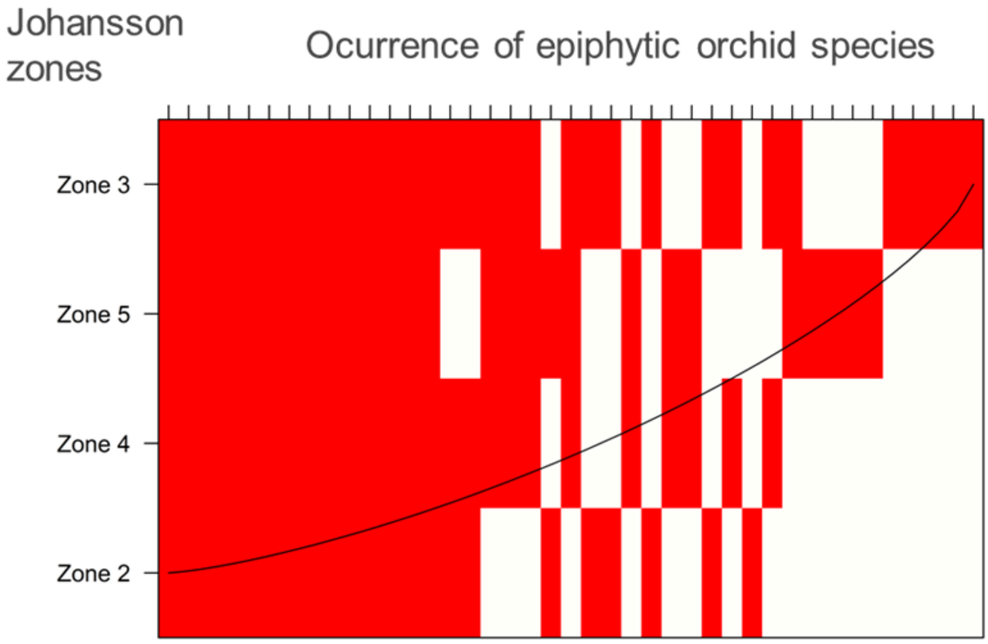

Figure 3.4 Presence (red colored) or absence (white colored) of epiphytic orchid species in each Johansson zone

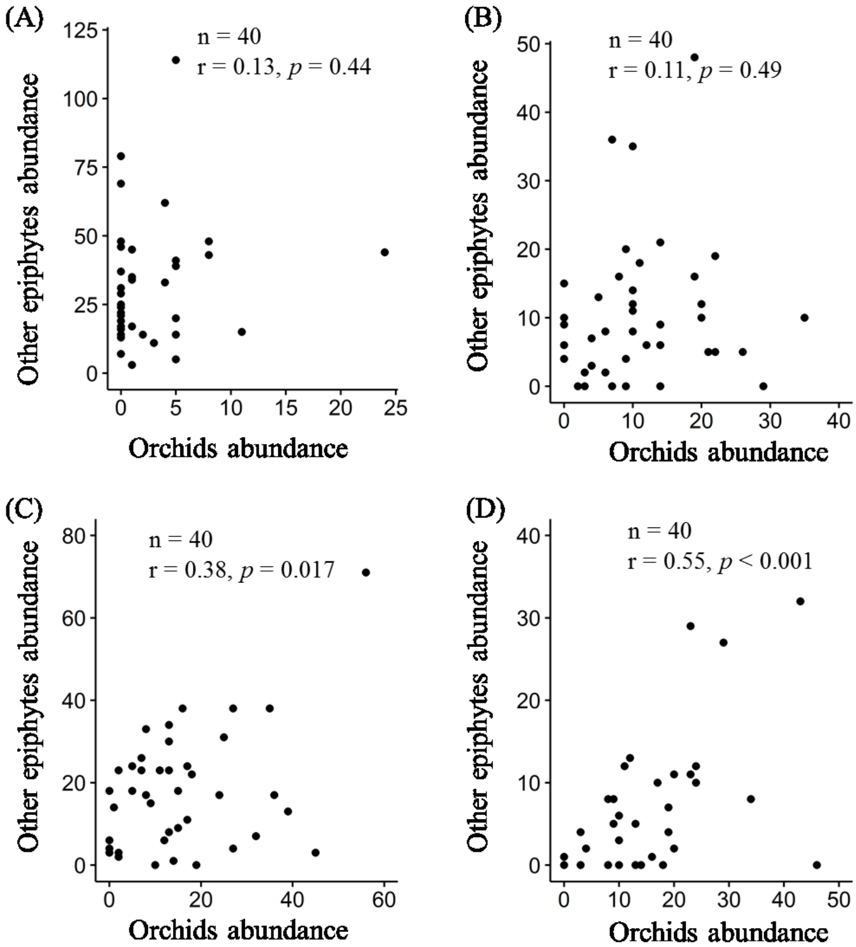

Figure 3.5 Relation between the orchids and other vascular epiphytes abundance: (A) trunk (zone 2), (B) inner crown (zone 3), (C) mid-crown (zone 4) and (D) outer-crown (zone 5) of *S. wallichii* trees.

Figure 3.6 Epiphytic orchids often found clumped together with other epiphytes such as ferns and mosses.

Tables

Table 3.1 Species composition of epiphytic orchid on forty *S. wallichii* trees at each Johansson zone. Asterisk (*) indicates Java Island endemic species (Comber 1990). Expected abundance were shown in parentheses. Differences in number for each species from the total number were tested with χ^2 test for only species with more than 20 individuals.

Orchid Species	Pseudo-bulb type*	Abundance in 40 host trees				Total	χ^2 value	*p* value
		Zone 2	Zone 3	Zone 4	Zone 5			
*Coelogyne miniata**	vp	21 (23)	114 (105)	141 (146)	132 (134)	408	1.012	0.798
Bulbophyllum flavescens	np	4 (15)	78 (67)	94 (93)	85 (86)	261	9.256	0.026
Eria multiflora	np	13 (11)	69 (52)	60 (72)	59 (66)	201	7.746	0.052
Pholidota globossa	vp	1 (7)	1 (34)	55 (47)	74 (43)	131	58.004	< 0.001
Pholidota carnea	vp	4 (6)	17 (26)	26 (36)	54 (33)	101	17.983	< 0.001
Schoenorchis juncifolia	np	7 (4)	27 (18)	19 (25)	16 (23)	69	9.999	0.019
*Ceratostylis backeri**	np	2 (4)	8 (17)	29 (24)	29 (22)	68	8.654	0.034
Coelogyne trinervis	vp	(3)	4 (15)	35 (21)	20 (19)	59	20.234	< 0.001
Dendrochillum cornutum	vp	(3)	16 (14)	13 (19)	25 (18)	54	8.220	0.042
Trichotosia annulata	np	2 (3)	19 (13)	28 (18)	2 (17)	51	20.875	< 0.001
Dendrobium spp. 1	np	2 (3)	13 (12)	23 (17)	10 (16)	48	5.266	0.234
Dendrochillum simile	vp	4 (2)	7 (7)	15 (10)	2 (9)	28	11.537	0.009
Bulbophyllum salaccense	snp	7 (2)	5 (7)	10 (10)	5 (9)	27	20.234	< 0.001
*Ceratostylis capitata**	np	7 (1)	8 (7)	9 (9)	2 (9)	26	25.370	< 0.001
Bulbophyllum ovalifolium	svp	4 (1)	5 (6)	13 (9)	3 (8)	25	9.878	0.020
Bulbophyllum stelis	np	2 (1)	3 (6)	10 (9)	9 (8)	24	2.274	0.518
Appendicula angustifolia	np	6 (1)	15 (5)	(8)	(7)	21	49.089	< 0.001
Cheratochillus biglandulosus	np	(1)	(4)	8 (8)	7 (5)	15		
Eria acuminata	bnp	(1)	2 (4)	12 (7)	(5)	14		
Flickingeria angustifolia	vp	(1)	2 (3)	2 (5)	7 (4)	11		
Bulbophyllum absconditum	svp	(1)	(3)	7 (5)	3 (3)	10		
Dendrobium heterocarpum	np	1 (1)	6 (2)	(4)	2 (3)	9		
Oberonia padangensis	np	1 (1)	8 (2)	(3)	(3)	9		
Eria spp. 1	vp	2 (0)	(2)	(3)	5 (3)	7		
Phreatia secunda	np		(2)	(3)	7 (2)	7		
Ceratostylis spp. 1	np		1 (2)	1 (2)	4 (2)	6		
Eria flavescens	vp	2 (0)	2 (2)	2 (2)	(2)	6		
Eria lamonganensis	vp		(2)	3 (2)	3 (2)	6		
Flickingeria spp. 1	vp	2 (0)	2 (2)	2 (2)	(2)	6		
Liparis pallida	vp	3 (0)	3 (2)	(2)	(2)	6		

Bulbophyllum tjadasmalangensis	svp	2 (0)	3 (1)	(2)	(2)	5
Flickingeria spp. 2	vp		2 (1)	1 (1)	(1)	3
Oberonia anceps	np		(1)	(1)	3 (1)	3
Bulbophyllum spp. 1	vp		1 (0)			1
Bulbophyllum spp. 2	vp		1 (0)			1
Ceratostylis spp. 2	np		1 (0)			1
Cleisostoma javanicum	np				1 (0)	1
Dendrobium spp. 2	np				1 (0)	1
Dendrobium spp. 3	np		1 (0)			1
Total		99	444	618	570	1731

*Pseudobulb type: vp visible pseudobulb, svp small but visible pseudobulb, snp small and not visible pseudobulb, np no pseudobulb, bnp big but not visible pseudobulb. Please refer to Figure 1.1.

Table 3.2 Coefficients of five generalised linear models with least AIC for epiphytic orchids abundance on the crown layer (zone 3, 4, and 5) of *S. wallichii* trees.

Model for epiphytic orchids abundance	ΔAIC	Coefficient		
		Host DBH (cm)	Number of branches (No)	Crown depth (m)
1	0.00	0.0147 ***	0.0025 ***	
2	2.00	0.0148 ***	0.0025 ***	-0.0004 ns
3	25.0	0.0172 ***		
4	26.3	0.0185 ***		-0.0052 ns
5	51.9		0.0036 ***	0.0319 ***

GLM with Poisson error distribution and log link function is used because the data is count data.
***$p<0.001$, ns not significant

Table 3.3 Coefficients of five generalised linear models with least AIC for epiphytic orchids species richness on the crown layer (zone 3, 4, and 5) of *S. wallichii* trees.

Model for epiphytic orchids species richness	ΔAIC	Coefficient		
		Host DBH (cm)	Number of branches (No)	Crown depth (m)
1	0.00	0.0072 *	0.0021 ns	
2	1.41	0.0094 **		
3	1.69		0.0026 *	0.0170 ns
4	1.96	0.0065 ns	0.0021 ns	0.0027 ns
5	2.77		0.0030 **	

GLM with Poisson error distribution and log link function is used because the data is count data.
**$p<0.01$, *$p<0.05$, ns not significant

Table 3.4 Coefficients of five generalised linear models with least AIC for epiphytic orchids diversity on the crown layer (zone 3, 4, and 5) of *S. wallichii* trees.

Model for epiphytic orchids diversity	ΔAIC	Coefficient		
		Host DBH (cm)	Number of branches (No)	Crown depth (m)
1	0.00	-0.0044 ns		
2	1.60	-0.0039 ns	-0.0004 ns	
3	2.00	-0.0044 ns		0.0002 ns
4	2.31			-0.0010 ns
5	3.01			

GLM with Gamma error distribution and inverse link function is used because the data is highly skewed.
ns not significant

4. Effect of tree density and host tree topography on epiphytic orchid community in *Schima wallichii* trees in a montane forest of West Java, Indonesia

Abstract

In attempt to investigate the effect of surrounded trees and host tree topography on epiphytic orchids abundance, species richness, and diversity, thirty-two of *S. wallichii* trees were selected randomly. Within a circle of radius 20m from each host tree, trees with DBH ≥20cm were recorded of their DBH, species name, and distance from other host tree, and the direction and aspect of slope which the tree stood. Density of trees surrounded host tree and host tree slope angle affect negatively on epiphytic orchid abundance. On the other hand, epiphytic orchid species richness and epiphytic orchid diversity in a host tree did not affected by number and density of surrounded trees nor by host tree slope angle and aspect. Better understanding about effect of surrounding and host tree site conditions on epiphytic orchids community may lead to better understanding about epiphytic orchids preservation and management in the study site and other tropical montane forests of West Java in general.

Introduction

Epiphytic plants are the major component of rainforest and the first community to decline when such ecosystem is threatened (Barthlott et al. 2001). Approximately 7.5% of all vascular plants are epiphytic species (Gentry and Dodson 1987). The largest group of vascular epiphytes is epiphytic orchid with about 18.000 species currently described (Gravendeel et al. 2004). Java Island has at least 731 species of orchids among of which 231 are endemic (Comber 1990). West Java has 642 species of orchids (Comber 1990).

The epiphytic habitat is quite constraining; the lack of relation to the soil implies a high risk of desiccation (Dubuisson et al. 2008). The distribution and abundance of epiphytic orchid may be limited due to availability of suitable host tree (Migenis and Ackerman 1993). The effect of host tree branch size and inclination on epiphytic plants abundance and species richness are well investigated (Garth 1964, Nieder et al. 2001). Large and massive epiphytic species usually grow on large branches, whereas species of moderate size grow on small ones (Johansson 1974).

Many authors have described the interaction of epiphyte including orchid and its host tree (ter Steege and Cornelissen 1989; Tremblay et al. 1998; Flores-Palacios and Garcia-Franco 2006; Hirata et al. 2009). On the other hand, there are very few researches about the effect of trees that are surrounding the host tree on epiphytic orchid community (Vacek and Leps 1996). Factor such as density of surrounding trees may affect the orchid community in a host tree directly or indirectly. Surrounding trees may affect the target tree positively as shelter or negatively as competitor (Vacek and Leps 1996). Report from Tremblay (2008) suggests that population size of a rare species of orchid (*Lepanthes eltoroensis*) would be affected by the excess foliage growth of its host and surrounding trees. Other effective factor is the effect of slope and aspect (compass direction of the slope) where a host tree stands. Within a forest, microsite differences exist at many different spatial scales from within a single branch until within stands of differing topography and aspects (Nadkarni et al. 2001).

Schima wallichii (DC.) Korth. (Theaceae) is an evergreen, medium-sized to large tree up to 45 m tall; up to 250 cm, with a steep buttress rarely up to 1.8 m high (Orwa et al. 2009). *S. wallichii* is one of the mountain species native to Java Island and is common and dominant in several mountain forests of West Java Province such as Mt. Gede, Mt. Pangrango and Mt. Sanggara (Fardhani et al. 2015, Muhamad et al. 2014, van Steenis 1972, Yamada 1975). *S. wallichii* is mostly used for fuel, poles and timber (Tamrakaar 1992). Several authors mentioned this species as one of host trees for the epiphytic plants such as bryophytes, orchids, and ferns (Marsusi et al. 2001, Puspitaningtyas 2007, Setyawan 2000).

In the present study, we tested the hypothesis: epiphytic orchid abundance, species richness, and diversity will be affected by number and size of tree that surrounding the host tree and host tree slope angle and topographical aspect influence the epiphytic orchid distribution in *S. walichii* as host tree. By studying those factors, better understanding about epiphytic orchid community in a host tree can be acquired. Better understanding of the interaction between epiphytic orchid and host tree species community may lead to better conservation management and strategy for orchid and its habitat.

Method

Study site

This study was conducted in a protected forest managed by a government-owned company in forestry, located at Legok Jero area (6°48’41S; 107°44’43E) in Mt. Sanggara, West Bandung Regency, West Java Province, Indonesia. For the complete description, please refer to Chapter 3.

Data collection

Thirty-two of *S. wallichii* trees were selected randomly for investigation of epiphytic orchid host with diameter at breast height (DBH) more than 20 cm (DBH; average 58.6 cm, maximum 95.7 cm, minimum 27.3 cm). Direction of slope (aspect) and angle of slope were measured for each host trees using Silva® compass and Haglofs® Vertex III. The nearest distance between each host tree was over 20 meters.

Number of species and individuals for epiphytic orchid attached on each host tree were recorded using both ground-based observation and single rope technique (Flores-Palacios and Garcia-Franco 2006, Taylor and Burns 2015). Binocular and 500mm Sigma® lens with Pentax K3® DSLR camera were used for ground-based observation. The clumped or creeping species were counted as one individual. Each orchid specimen was sampled or photographed for later identification using taxonomic literature by Comber (1990).

In attempt to investigate the effect of surrounded trees and host tree topography on epiphytic orchids abundance, species richness, and diversity within a circle of radius 20m from each host tree, trees with DBH ≥20cm were recorded of their DBH, species name, and distance from other host tree, and the direction and aspect of slope which the tree stood. Each measured tree was photographed or sampled of its shoot for later identification using taxonomic literature by van Steenis (1972). Data was collected from July 29th to August 7th, 2018.

Analysis

Orchid diversity was measured using Shannon-Wiener index of diversity (*H*') (Odum, 1953). We measured the orchid diversity at each host tree and the diversity of orchid community at the study site. Data was calculated by the formula

$H' = -\sum_{i=1}^{s}(pi \ln pi)$,

where H' is the Shannon-Wiener index of diversity, s is the number of species in community, pi is the proportion of total abundance represented by i^{th} species.

To determine the factors that affect epiphytic orchid abundance, species richness, and diversity, Generalised Linear Model (GLM) was constructed. The explanatory variables used for GLM were number of other vascular epiphytes, density and size of trees surrounding around the host tree, and direction and angle of slope which that host tree stood. Host tree direction (aspect) was linearized using the formula [1-cosine (aspect in degrees)] + [1-sine (aspect in degrees)] (Eckhardt and Menard, 2008). So that northeasterly aspects had the lowest values and southwesterly aspects had the highest values.

Variable Inflation Factor (VIF) was used to screen covariates and to avoid multicollinearity by removing the variable with VIF>5 (Mansfield and Helms 1982; Bagheri and Midi 2009). GLM with a Poisson error distribution and a logarithmic link function is used for modelling epiphytic orchid abundance and species richness since both variables generally satisfies the Poisson error distribution as a count variable (Bolker et al. 2009, Kwon et al. 2018). On the other hand, GLM with Gamma error distribution with an inverse link function is used for modelling the diversity of orchid (Cayuela et al. 2006, Crawler 2002, Everwand et al. 2014). Models were selected and ranked from the lowest value of AIC (Akaike's Information Criterion). These analyses were performed using R version 3.3.0 (R Development Core Team 2016) running in RStudio Version 1.0.136 (RStudio Team 2016).

Result

There was no multicollinearity between explanatory variables was found (VIF<5) indicating no correlation among factors so that all factors can be included in GLMs. Five models with lowest value of AIC for orchid abundance were shown in Table 4.1. Among them, four models suggested the significant negative effect of number of surrounded trees on orchid abundance. one model suggested the significant negative effect of basal area of surrounded trees on orchid abundance. Host tree slope angle had significant negative effect on orchid abundance in all five models. Some models suggested negative effect of host tree aspect on orchid abundance, although it was not statistically significant.

For orchid species richness, five models with lowest value of AIC were shown in Table 4.2. All models showed no significant effect of all factors on the species richness. All models also showed no significant effect of all factors on the epiphytic orchid diversity (Table 4.3). Based on this result, it was clearly shown if epiphytic orchid species richness and epiphytic orchid diversity in a host tree did not affected by number and density of surrounded trees nor by host tree slope angle and aspect.

Discussion

In this study, surrounding trees affect negatively for epiphytic orchids growth because it may block the required sunlight and shaded the host tree. Low and high levels of light appear to affect population size of the orchid (Tremblay 2008). In addition, beside affected by the number of surrounded trees, light availability also decreased with increasing basal area (Comeau et al. 2005). On the other hand, both epiphytic orchids species richness and diversity were not affected by the number and basal area of trees surrounding host tree (Table 4.2 and 4.3). Apparently, rather than factors outside the host tree such as number of trees surrounded host tree and its basal areas, epiphytic orchid species richness and diversity are depended on host tree condition such as tree size because it determines the number of vertical microhabitats inside the crown (Flores-Palacios and Garcia-Franco 2006; Hirata et al. 2008).

Although the effect of host tree slope angle and aspect on epiphyte distributions including epiphytic orchids has received little attention in the literature, the effect of slope and aspect on terrestrial plant distributions is well established. For example, slope and aspect has significant effects on plant species associations (Badano et al. 2005), floristic competition (Kutiel 1992) growth differences in tree seedlings (Raaimakers 1994, Itoh 1995), and forest composition (Holland and Steyn 1975).

In this study, host tree slope angle affected the epiphytic orchids abundance negatively (Table 4.1). This may be caused by the effect of slope on host tree growth and then affecting epiphytic orchid abundance. The average of slope angle of the host tree was 19.78 degree and categorized as gentle to moderate slope (Anbalagan et al. 2007, Sharma et al. 2009). Host trees grown on steeper slope might be shaded and accept less sunlight by its terrain and neighbouring trees in uphill direction compared with host trees grown in flat area. Furthermore, light conditions are affected both by the local neighbourhood (i.e. biotic) interactions and by abiotic factors such as latitude and topography, including slope and aspect. Both latitude and topography are the major abiotic factors influencing the intensity and the direction of sunlight (Lang et al. 2010). In contrast, host tree slope angle showed positive effect both on epiphytic orchid species richness (Table 4.2) and diversity (Table 4.3) although it was not significant.

Effect of aspect on epiphytic community had been documented by researchers. For example, for some epiphytic plants such as mistletoes, germination success of in cooler temperate forests increases on host aspects oriented toward the sun (Taylor and Burns 2016). Within a forest, microsite differences (of epiphytic host trees) exist at many different spatial scales: within a single branch; between branches at different heights of the tree; between trees of different architecture; and within stands of differing topography and aspects. (Nadkarni et al. 2001). However, in tree community, slope aspect has no significant effect to stem density and species richness of trees based on study in a tropical rainforest of Amazon (Laurance et al. 2010). Those finding is similar with this study. There was no significant effect of host tree aspect on epiphytic orchids abundance (Table 4.1), species richness (Table 4.2) and diversity (Table 4.3). Seemingly, both species richness of trees and epiphytic orchids inhabit the trees are not significantly affected by slope aspect.

Conclusion

Number and basal area of trees surrounding host tree had negative effect on orchid abundance. Host tree slope angle also has negative effect on orchid abundance. However, host tree aspect did not affect epiphytic orchid abundance. Furthermore, orchid species richness and diversity were not affected by number and basal area of trees surrounding host tree nor by host tree slope angle and aspect. Better understanding about effect of surrounding and host tree site conditions on epiphytic orchids community may lead to better understanding about epiphytic orchids preservation and management in the study site and other tropical montane forests of West Java in general.

Tables

Table 4.1 Coefficients of five generalised linear models with least AIC for epiphytic orchids abundance on *S. wallichii* trees

Model for epiphytic orchids abundance	ΔAIC	Coefficient							
		Number of surrounded trees (radius 20 m)		Basal area of surrounded trees (radius 20 m)		Host tree slope angle		Host tree aspect	
1	0.00	-0.0195	**			-0.0067	**		
2	0.33	-0.0147	**	-0.0363	ns	-0.0060	**		
3	1.83	-0.0195	***			-0.0067	***	-0.0111	ns
4	2.29	-0.0148	**	-0.0353	ns	-0.0061	**	-0.0060	ns
5	7.03			-0.0992	***	-0.0051	**		

GLM with Poisson error distribution and log link function is used because the data is count data.
****p*<0.001, ***p*<0.01, **p*<0.1, ns not significant

Table 4.2 Coefficients of five generalised linear models with least AIC for epiphytic orchids species richness on *S. wallichii* trees

Model for epiphytic orchids species richness	ΔAIC	Coefficient							
		Number of surrounded trees (radius 20 m)		Basal area of surrounded trees (radius 20 m)		Host tree slope angle		Host tree aspect	
1	0.00								
2	1.23							0.0555	ns
3	1.85					0.0017	ns		
4	2.00	0.0006	ns						
5	2.00			0.0007	ns				

GLM with Poisson error distribution and log link function is used because the data is count data.
ns not significant

Table 4.3 Coefficients of five generalised linear models with least AIC for epiphytic orchids diversity on *S. wallichii* trees

Model for epiphytic orchids diversity	ΔAIC	Coefficient			
		Number of surrounded trees (radius 20 m)	Basal area of surrounded trees (radius 20 m)	Host tree slope angle	Host tree aspect
1	0.00				
2	1.02				-0.0321 ns
3	1.25		-0.02017 ns		
4	1.34	-0.0032 ns			
5	1.98			0.0003 ns	

GLM with Gamma error distribution and inverse link function is used because the data is highly skewed.
ns not significant)

5. Swot analysis for orchid conservation in a forest at Mount Sanggara, West Java, Indonesia

Abstract

Mount Sanggara, West Java, Indonesia, specifically in Legok Jero area has orchid diversity consisting of 46 epiphytic and four terrestrial. The diversity indexes (*H'*) were categorized as medium both for epiphytic and terrestrial species. The problems in Mount Sanggara are due to conversion of forest into coffee plantation and illegal logging although the forest status is protected forest. Besides, orchids are also threatened by illegal collecting. Strategic management is needed to solve these problems. The purpose of this study was to create the proper strategies to manage the forest in a sustainable way for orchid species, surrounding villages, company, and the sustainability of the orchid community itself. This paper explores internal and external factors by SWOT analysis to formulate management strategies. Data were gathered by structured and unstructured interview and questionnaire. The instruments were distributed to company as stake holder, farmer group, and local residents. From the SWOT analysis, several strategies were proposed to optimize the strengths and opportunities for the purpose of overcoming the weaknesses and to avoid the threats. Consequently, the proposed strategies can be an alternative for stakeholder to manage this forest sustainably not only for local residents but also for the orchid community itself.

Introduction

Orchidaceae is one of the largest families of class angiospermae in the world (Brian and Ritterhausen 1978). Indonesia has 5,000 species out of 25,000 orchid species in total (Gunadi 1986, Banks 2004). There are two major types of orchid species based on the habitat, epiphytic and terrestrial (Hew and Young 2008). Epiphytic orchids attach on host tree trunk for living, while terrestrial orchids grow from inside the soil, humus or litter (Hew and Young 2008).

Java Island has at least 731 species of orchids, 231 are endemic (Comber 1990). In West Java, there are 642 species of orchids (Comber 1990). The habitat loss caused by forest conversion into plantation, farming, and settlement areas has threatened orchid population in Java. Based on data from Forest Watch Indonesia (2014), natural forest cover of Java Island in 2013 declined to 675,000 ha from 1,002,000 ha in 2009. Apart from natural forests, there are limited production forests (394,314 ha) and special function forests (1,562,733 ha). The massive forest conversion is occurring in West Java Province because it is the most populated province in Indonesia with more than 46 million inhabitants (Provincial Office of West Java 2011).

Located at the border between Subang Regency and West Bandung Regency which are included in North Bandung Area (Kawasan Bandung Utara) mountain, several forests are still in good condition. Therefore, the diversity of orchid in this area was also high as reported by Agustina et al. (2008), who identified 41 species of orchids. Based on previous report (Fardhani et al. 2015), Mount Sanggara, specifically in Legok Jero area had orchid diversity consisting of 46 epiphytic and four terrestrials in 0.17 ha study area. Similar researches show the importance of the study of orchid diversity in a certain area in an attempt to conservation (Puspitaningtyas 2007, Tsiftsis et al. 2008; Yahman 2009; Yulia and Budiharta 2010; Aisah and Istikomah 2014).

The problems to which Mount Sanggara has been exposed are forest conversion into coffee plantation and illegal logging, despite the fact that the forest status is protected forest managed by a government-owned company. Besides, orchid and several plants such as ferns, wild flowers, and pitcher plant, are threatened by illegal collecting. Strategic management is needed to solve these problems. Where local people are interested in the conservation and traditional use of their lands, resources, and so forth, on condition that their fundamental human rights are respected, conflicts do not arise between the people's rights and interests, and the objectives of protected areas (*IUCN 2000*).

SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis is an instrument for making strategic planning which diagnoses internal strengths and weaknesses of organisations and formulates the opportunities and threats of the environment (Rauch 2007). SWOT is a tool designed to be used in the preliminary stages of decision-making on the one hand and as a precursor to strategic management planning on the other (Srivastava et al. 2005). In this analysis, all factors influencing the operational environment are diagnosed with greater detail (Kotler 1994; Shrestha et al. 2004). This analysis has been widely used in forest environment studies (Pesonen et al. 2001, Rauch 2007, Masozera et al. 2006, Reihanian et al. 2012).

The purpose of this study was to create the proper strategies to manage the forest in sustainable way for orchid species, surrounding villages, company, and the sustainability of the orchid community itself. SWOT analysis could be expected to serve as a proper tool to formulate strategic management planning for orchid conservation in Legok Jero area.

Materials and methods

This study was conducted at Legok Jero Area, Mount Sanggara (6°48'41.47" S; 107°44'43.80"E) and Sunten Jaya village, West Bandung Resident, West Java Province, Indonesia (Figure 5.1A). Legok Jero was chosen because the abundance of orchid here is the most. The altitude in this area is around 1,700 m a.s.l. The study site is secondary forest with *Schima wallichii* trees as dominant species. Other components are the coffee plantation, in which coffee trees were planted under the shade of crown trees and the crop fields (Figure 5.1B). The forest is protected from timber extraction under the management of a government-owned company in forestry. Sunten Jaya village is chosen for this study because the coffee plantation belonged to a farmer group of this village. The coffee plantation is part of a program from the company called Forest Management with Local Community (*Pengelolaan Hutan Bersama Masyarakat*, PHBM). The company allows nearest local community to utilize forest with under shade coffee plantation to avoid forest destruction and illegal logging.

Data were gathered by structured and unstructured interview and questionnaire. The data collections were performed from 10 to 12 August 2015. The sources included the staff of a state-owned company and a head of the farm group. The questionnaire was given to 340 households of Sunten Jaya village including members of farm group during September-October 2015. Interview was held face to face to the company forest manager and head of the farm group. The farm group members and village residents were given questionnaire. In questionnaire, simple Yes/No, multiple choices, and fill-in-the-blank types of questions were used. The questions were kept simple to avoid misunderstanding. Some of the questioned respondents took the questionnaire home and returned it to the data collector later. This is mainly because they were at work during the day and it was not convenient to fill out the form directly and because they preferred to take time to fill out the questionnaires. However, some other respondents filled the questionnaire directly in front of the collector at the farm.

Management strategies for orchid and its habitat were formulated using SWOT (Strength-Weakness-Opportunity-Threat) analysis. This analysis is representing a systematic and comprehensive diagnosis of factors relating to a new product, technology, management, or planning (Baycheva and Wolfslehner 2015). SWOT matrix, has often been used in the field of business and extended to that of natural resource management in order to assess a given decision, project or policy directive in a systematic manner (Schmoldt et al. 2001 in Reihanian et al. 2012). SWOT analysis doesn't determine whether a strategy is correct or incorrect, but this analysis helps us to arrange several alternatives to overcome problems based on internal factors (strengths and weaknesses) and external factors (opportunities and threat). Applying SWOT analysis provides a good overview and makes it easy to pinpoint important problem areas (Rauch 2007).

Both primary and secondary data were the sources for SWOT analysis as shown in Figure 5.2. The method is based on two tiers of analysis which are conducted separately (Reihanian et al. 2012): (i) First step is to analyse internal factors which contain strengths and weaknesses. (ii) Second step is to analyse external factors which contain relevant opportunities and threats.

The most important part in SWOT is scanning the internal and external factors. The internal factors were classified as strengths (S) and Weaknesses (W). The external factors were classified as Opportunities (O) and Threats (T). Then matrix of Internal Factors Evaluation (IFE) and the matrix of External Factors Evaluation (EFE) were made. The factors then were weighted and calculated to get final score.

The following section describes the process of SWOT analysis:

1. Each factor was given a coefficient between 0 and 1, standing for "not important" and "most important". The total score of the coefficient in each matrix factor should be equal to 1 in both IFE Matrix and EFE Matrix.
2. Each factor then scored between 1 and 4. 1 standing for poor, 2 standing for average, 3 standing for above average, 4 standing for superior (Lodato 2014).
3. Final score of each factor was determined by multiplied coefficient with score.
4. After total score of each factor was calculated, they were summed to calculate the final score for each matrix (IFE and EFE).
5. For IFE Matrix, if the value was less than 2.5 (below the average), it meant that the strengths were less than the weaknesses; if it was more than 2.5 (above the average), it meant the strength were more than the weaknesses.
6. For EFE Matrix, if the value was less than 2.5 it meant that the opportunities were less than the threats; if it was more than 2.5, it meant the opportunities were more than the threats (Reihanian et al. 2012; Lodato 2014).
7. The internal and external factors then were put into SWOT matrix to plan the management strategies (Strength-Opportunity (SO) strategies; Strength-Threat (ST) strategies; Weakness-Opportunity (WO) strategies; Weakness-Threat (WT) strategies).

8. SWOT matrix was made by pairwise matching of each strength with each opportunity; each strength with each threat; each weakness with each opportunity; and each weakness with each threat.
9. After matching each factor, the four groups of management strategies were then planned.

Result and discussion

Internal Factor Evaluation Matrix (IFE)

The IFE Matrix is shown in Table 5.1. Six factors were identified as strengths of this study site. The weight allocated to these factors ranged from 0.07 to 0.12. The rating scores ranged from 2 to 4. The highest strength factor of this location was 'the study site status as protected forest' (weighted score = 0.48). Four factors were detected as weakness of this study site. The weight allocated to these factors ranged from 0.09 to 0.13. The rating scores ranged from 1 to 2. The weakest factor considered from the study site is 'the low number of terrestrial orchid species' (weighted score = 0.26). The total score of the IFE Matrix was 2.37, less than 2.5, implying that the strengths were less than weaknesses.

External Factor Evaluation Matrix (EFE)

The result of EFE matrix is shown in Table 5.2. There were six factors identified as opportunities. The weights ranged from 0.06 to 0.15. The rating scores ranged from 2 to 4. The highest opportunity factor of this study site was PHBM program was able to reduce illegal logging in the location' (weighted score = 0.6). Three factors were identified as threats. The weights were ranged from 0.09 to 0.15. The rating scores ranged from 2 to 4. The biggest threat factor considered for this study site was the 'PHBM program threat the sustainability of terrestrial orchid' (weighted score = 0.6). The total score of EFE matrix was 3.21, which would imply that opportunities were more than threat.

In order to overcome the weaknesses and to harness the opportunities, by pair wise matching in SWOT matrix, 14 strategies were proposed for the study site. The proposed strategies were divided into four groups: SO strategies, WO strategies, ST strategies, and WT strategies (Table 5.3).

Discussion

Applying SWOT analyses provides a good overview and makes it easy to pinpoint important problem areas (Rauch 2007). SWOT analysis helped us to understand the factors (both internal and external) which would affect the forest management, local resident life, and orchids and forest sustainability at the study site where the PHBM program is implemented in West Java Province. We now understood that the PHBM program had important role to reduce illegal and destructive forest utilization. On the other hand, we also understood that the PHBM program might negatively affect the terrestrial orchid species. Forest floor clearance is the major threat for terrestrial orchid conservation besides collecting the wild orchid species (Swarts and Dixon 2009). At the study site, in order to plant coffee trees and crops under the PHBM program, farmer cleared the forest floor including some understory trees (Figure 5.1B). Not only affecting the terrestrial orchids, research by Hundera et al. (2013) in Ethiopia suggested the intensification of under shaded coffee plantation can reduce the epiphytic orchid species richness by reducing the density of trees and crown cover.

None of the terrestrial and epiphytic orchids were considered as important or charismatic species at the study site by SWOT analysis (Table 5.1). However, we cannot let those species extinct only because they are common species. Conservation of common species is needed to ensure that they do not become uncommon or rare and thus can maintain their key ecological and functional roles in an ecosystem (Gaston 2010, Lindenmayer et al. 2011). The implementation of the PHBM program should be carefully conducted to reduce the negative effect.

Based on the SWOT analysis, we proposed strategic management. All the strategies that were proposed have not been implemented yet. However, these strategies can become an alternative for forest management in this area. We suggest expanding the area of the PHBM program to increase the number of local residents involved so that they would be benefited by the program. The income of local residents is mostly low and depends on the forest for fulfilling daily needs. Increasing the number of local people who are involved in the PHBM program will lead income for more number of households. Local people may be interested in conserving biodiversity only if certain rights to use lands and forests are allocated to them (Harada 2003). Where local people are interested in the conservation and traditional use of their lands, resources, and so forth, on condition that their fundamental human rights are respected, conflicts do not arise between the people's rights and interests, and the objectives of protected areas (IUCN 2000). Agroforestry provides a potentially valuable conservation tool that can be useful for reducing land-use pressure and enhancing rural livelihoods (Bhagwat et al. 2008). However, we also suggest considering about avoiding destructive forest floor clearing that will affect negatively the population of terrestrial orchid and other native plant species.

The area of PHBM program can also be used for ecotourism together with coffee plantation. The natural orchid habitat with many epiphytic species can attract tourist to this area. Such ecotourism can bring lots of benefit to rural zones. Ecotourism in this area may also help to preserve local and traditional value of Sundanese people as part of tourist attraction. Rural tourism will cause the development of social and economic aspect of a village in long terms (Mahmoudi et al. 2011). With ecotourism, the local resident dependency on exploitative forest resources utilization may be controlled.

This study examines the strengths, weakness, opportunities and threats of orchid community in a protected forest area in Mount Sanggara, West Bandung Regency, West Java, Indonesia. Applying SWOT analysis provided a good overview and made it easy to point the important problem areas. From the final score of SWOT analysis, the Internal Factors Evaluation score was 2.37 (<2.5), indicating that the strengths were less than weaknesses. The score of External Factors Evaluation was 3.21, indicating the opportunities were more than threats. Several strategies were proposed to optimize the strengths and the opportunities for the purpose of overcoming the weaknesses and of avoiding the threats. These results may help the forest managers to analyze the problems in the PHBM program implementation for orchids and forest sustainability. The proposed strategies can become an alternative solution for further research on the PHBM program implementation in the study site.

Figures and Tables

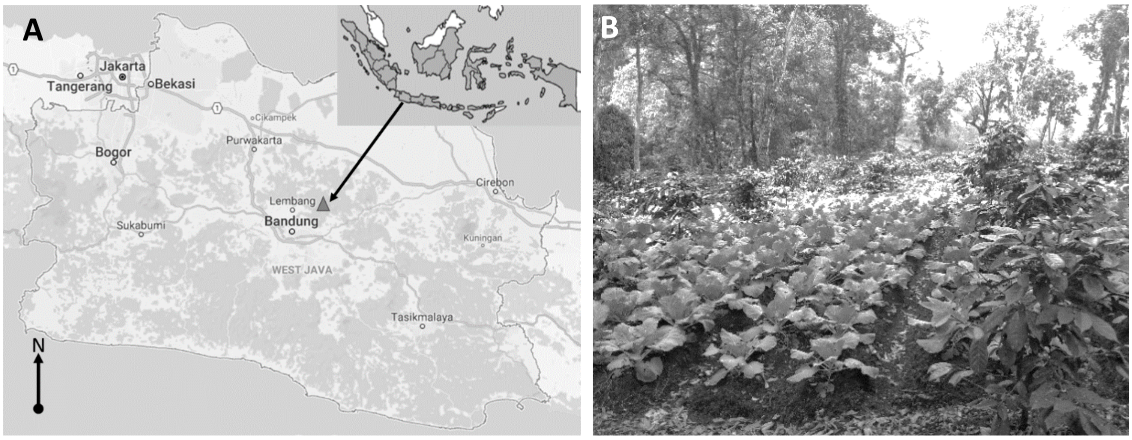

Figure 5.1 (A) Study site map of Mount Sanggara, West Java, Indonesia, (B) A crop field made between coffee tree lines on the cleared forest floor surrounded by the tall trees.

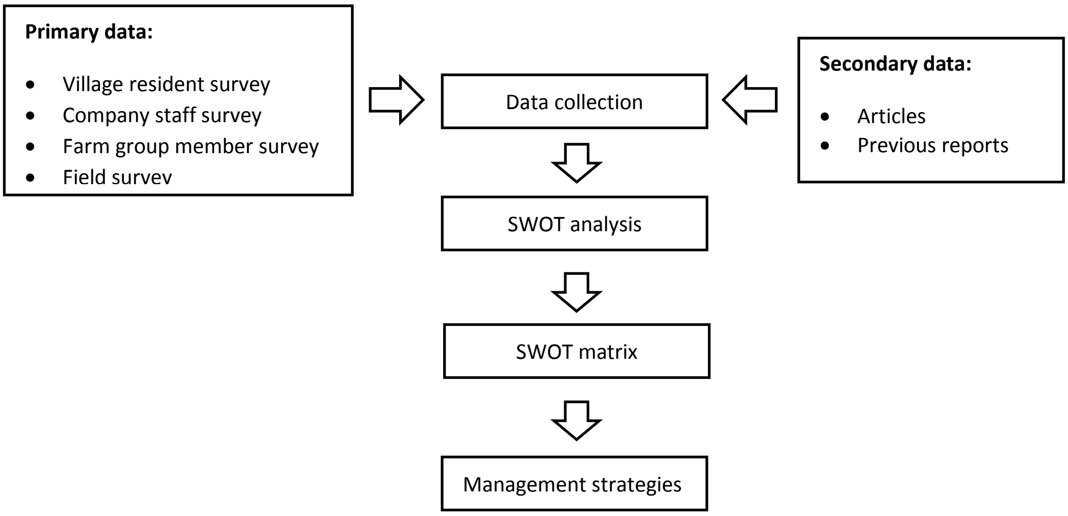

Figure 5.2 Research methodology outline for SWOT analysis

Tables

Table 5.1 Internal Factor Evaluation Matrix

	Internal Factor	**Code**	**Weight**	**Rating**	**Weighted score**
Strengths	The location is protected forest	S1	0.12	4	0.48
	The location is proper habitat for orchid growth	S2	0.10	3	0.30
	High number of epiphytic orchid species (46 species)	S3	0.08	2	0.16
	High abundance of epiphytic orchid.	S4	0.07	4	0.28
	There are 7 epiphytic orchid species endemics to Java Island.	S5	0.10	4	0.40
	Orchid species is distributed evenly.	S6	0.09	2	0.18
Weaknesses	Low number of terrestrial orchid species (4 species)	W1	0.13	2	0.26
	Low abundance of terrestrial orchid	W2	0.12	1	0.12
	There is no economically valuable orchid in study site	W3	0.09	1	0.09
	There is no law protected orchid species in study site	W4	0.10	1	0.10
Total score			1.00	-	2.37

Table 5.2 External Factor Evaluation Matrix

	External factor	Code	Weight	Rating	Weighted score
Opportunity	PHBM program reduced illegal logging in the location.	O1	0.15	4	0.60
	Local residents would be benefited by PHBM program.	O2	0.13	4	0.52
	Orchids were not considered as main economic commodity for local residents	O3	0.10	3	0.30
	Income of local residents was mostly low (under 100 USD/month).	O4	0.15	3	0.45
	Local residents already knew if the Mount Sanggara forest was orchid habitat	O5	0.07	2	0.14
	Local residents understood if orchid presences needed to be conserved.	O6	0.06	2	0.12
Threat	PHBM program threatens the sustainability of terrestrial orchid.	T1	0.15	4	0.60
	Most of the local residents depended on company forest for daily need.	T2	0.10	3	0.30
	Local residents were not familiar with legally protected orchid species.	T3	0.09	2	0.18
Total score			1.00	-	3.21

Table 5.3 Management strategies for orchid and habitat conservation at Mount Sanggara, West Java, Indonesia

Strength-Opportunity (SO) strategies

- Expand the area of the PHBM program (S1, O1, O2)
- Develop ecotourism area with coffee plantation and orchid habitat for the attractions (S1, S2, S3, S4, S5, S6, O1, O2, O5, O6)
- Promote cultivation of native orchid as new economic commodity for local residents (S2, S3, S4, S5, S6, O3, O4)
- Training program for local residents about native orchid cultivation to increase their income (S2, S3, S4, S5, S6, O3, O4, O6)

Weakness-Opportunity (WO) strategies

- Modify the expansion of coffee plantation to avoid the degradation of terrestrial orchid and other forest floor plants diversity (W1, W2, W4, O1, O2, O6)
- Increase the local resident role in the PHBM program (W3, W4, O1, O2, O4)

Strength-Threat (ST) strategies

- Company has to provide strict supervision related to the PHBM program (S1, S5, T1)
- Secure the forest to avoid illegal utilization (S1, T2)
- Education program for local residents about sustainable forest utilization for their daily needs (S1, S2, T2)
- Company and stakeholder have to provide information to local residents about legally protected orchid to avoid illegal collecting (S5, T3)

Weakness-Threat (WT) strategies

- Termination of extension of coffee plantation area (W1, W2, T1)
- Change the method for coffee planting to be safer for understory, shrub, and ground plants. (W1, W2, T1, T2)
- Re-introduction program to increase terrestrial orchid population (W1, W2, W3, T1)
- Strict law enforcement to avoid destructive and illegal forest utilization (W1, W2, W4, T1, T2)

Note: Codes of each matrix relating to each strategy have been shown in parentheses

6. General discussion and Conclusion

General Discussion

Diversity of epiphytic orchids in S. wallichii trees and factors affecting it community

Based on previous report on this location by Fardhani et al. (2015), there were 46 of epiphytic orchid species at the study site with no regards to host species. In this study, total 39 of epiphytic orchid species grew on *Schima wallichii* trees at the study site among which three were endemic species of Java Island. Among 39 epiphytic orchids, six species were new records on *S. wallichii* trees. The most abundant species is *Coelogyne miniata* (Figure 6.1). This species is endemic to Java Island and has beautiful bright orange-red flowers (Comber 1990). The species richness of orchid was higher than those of some previous reports from East Java, with only two species of orchid attached on this tree species from no more than three tree individuals observed (Setyawan, 2000, Marsusi 2001, Puspitaningtyas, 2007).

The distribution tendency of orchid individuals in *Schima wallichii* tree was different among species. In detail, some species distributed only in crown while some other inhabited both on trunk and in crown. Krömer et al. (2007) said that among vascular epiphytes, habitat specialization occurs. Similar phenomenon was observed in epiphytic orchids which inhabit *S. wallichii* tree in this study. From this study, we could understand that most of epiphytic orchid species do not colonize certain zone of *S. wallichii* tree but distribute in most zones, mostly in crown.

At this study site, fern dominancy became decreasing along increasing height of each tree, while orchid became increasing. Study in forest of Bolivian Andes (Krömer et al. 2007) and Guyana (ter Steege and Cornelissen 1989) show that orchids tend to grow at higher zone because they can adapt to the scarce resource condition.

Based on several researches, mid-crown zone (Johansson zone 4) contain the highest abundance and species richness of vascular epiphytes (Nieder et al. 2001, ter Steege and Cornelissen 1989). Orchids also tend to colonize the mid-crown zone of host where microclimatic conditions and host characteristics are probably most favourable for their survival in a tropical dry forest (de la Rosa-Manzano et al. 2014). However, in this study, such phenomena were not observed. Such that differences in both orchid abundance and species richness among three zones in crown were not significant. Therefore, all crown zones of *S. wallichii* tree can be presumably has similar microclimatic condition for epiphytic orchids inhabiting this tree species in a tropical montane forest of West Java.

Neither linear relationship between height of *S. wallichii* and epiphytic orchid species richness nor diversity were observed. In addition, the orchid species richness and diversity were not affected by host tree height. According to Andersohn (2004), height of host tree did not affect epiphyte diversity, while based on our finding, only plant height affected the abundance of epiphytic orchid positively. Relationships between epiphyte species richness and tree diameter (DBH) have been reported (Flores-Palacios and Garcia-Franco 2006, Taylor and Burns, 2015). Epiphytes abundance also showed a positive relationship with tree diameter, a larger host tree would contain more number of epiphytes (Dunn 2000, Magalhaes and Lopes 2015). This study also showed similar tendency with that, larger *S. wallichii* tend to host more orchid species and individuals. Orchids tend to be restricted to larger host trees because of their preference for larger diameter supports (Zimmerman and Olmsted 1992). A larger host tree provided a greater available surface area for orchid to attach (Migenis and Ackerman 1993, Muñoz et al. 2003, Bergstrom and Carter 2008).

The tree size (DBH) and the number of branches in the crown had positive effect on the abundance and species richness of epiphytic orchids in *S. wallichii* trees. Therefore, a host tree with larger size and greater number of branches would host more orchid individuals and more orchid species. Host tree size is one of the main factors influencing vascular epiphytes richness (Hirata et al. 2009). Epiphytes richness will depend on tree size because it determines the number of vertical microhabitats inside the crown (Flores-Palacios and Garcia-Franco 2006). Larger diameter trees will accumulate epiphytic species faster than smaller trees, once the first epiphyte have established (Taylor and Burns 2015). Because epiphytes including orchids tend to accumulate in larger and older host trees, in general, the diversity and abundance of epiphytes are therefore positively correlated to the successional stage of a forest (Nieder et al. 2001). Similar phenomena were observed in the study site. Larger *S. wallichii* trees showed tendency to host more abundant and various epiphytic orchid species compared with the smaller one. Conservation of *S. wallichii* tree with large size would lead to the conservation of various species of epiphytic orchids in the tropical montane forest of West Java.

Number of host tree branches in crown zones had positive effect on epiphytic orchid abundance. This result added new insight to the previous studies about the effect of branches of the host tree on vascular epiphytes abundance. Based on the study by Nieder et al. (2001) branch size determines epiphytic plants abundance. Trees lacking of large diameter branches due to their branching pattern is considered as poor hosts for epiphytes (Garth 1964). Beside the size, branch inclination inversely correlates to the number of epiphyte individuals including orchid (Rudolph et al. 1998). Horizontal branches support epiphyte communities because they allow the accumulation of crown soil as a critical water source (Enloe et al. 2006, Nadkarni and Matelson 1991, Taylor and Burns 2015).

From our observation in the study site, emergent *S. wallichii* trees had almost branchless tall cylindrical trunk up to about 20 meters height and had dense crown with numerous branches (146 in average). We observed that many branches inclined almost horizontally which would make epiphytic orchids easier to attach and colonize. Thus, based on this research, it was clarified that along with the branch size and inclination, epiphytic orchid abundance would also be affected by the number of branches in a host tree.

Both orchid diversity and species richness was not affected by crown depth (zone 3, 4, and 5). Based on Nieder and Zotz (1998), the Johansson's zonation does not reflect height and then, each host tree may have different zone height according to its structure. In the study site, short-canopied tree could host orchid species just as many as the long-canopied tree if that tree had numerous branches. For orchid abundance, only one model suggested the significant positive effect of crown depth (zone 3, 4, and 5). Crown depth didn't show significant effect on orchid species richness because from our observation, in the crown zones, most epiphytic orchid species spread their roots on comparatively horizontal branches rather than on more vertical branches.

In this study, surrounding trees affect negatively for epiphytic orchids growth because it may block the required sunlight and shaded the host tree (Figure 6.2). Low and high levels of light appear to affect population size of the orchid (Tremblay 2008). In addition, beside affected by the number of surrounded trees, light availability also decreased with increasing basal area (Comeau et al. 2005). On the other hand, both epiphytic orchids species richness and diversity were not affected by the number and basal area of trees surrounding host tree. Apparently, rather than factors outside the host tree such as number of trees surrounded host tree and its basal areas, epiphytic orchid species richness and diversity are depended on host tree condition such as tree size because it determines the number of vertical microhabitats inside the crown (Flores-Palacios and Garcia-Franco 2006; Hirata et al. 2008).

Although the effect of host tree slope angle and aspect on epiphyte distributions including epiphytic orchids have received little attention in the literature, the effect of slope and aspect on terrestrial plant distributions is well established. For example, slope and aspect has significant effects on plant species associations (Badano et al. 2005), floristic competition (Kutiel 1992) growth differences in tree seedlings (Raaimakers 1994, Itoh 1995), and forest composition (Holland and Steyn 1975).

In this study, host tree slope angle affected the epiphytic orchids abundance negatively. This may be caused by the effect of slope on host tree growth and then affecting epiphytic orchid abundance. The average of slope angle of the host tree was 19.78 degree and categorized as gentle to moderate slope (Anbalagan et al. 2007, Sharma et al. 2009). Host trees grown on steeper slope might be shaded and accept less sunlight by its terrain and neighbouring trees in uphill direction compared with host trees grown in flat area. Furthermore, light conditions are affected both by the local neighbourhood (i.e. biotic) interactions and by abiotic factors such as latitude and topography, including slope and aspect, because it influencing the intensity and the direction of sunlight (Lang et al. 2010). Effect of aspect on epiphytic community had been documented by researchers. For example, for some epiphytic plants such as mistletoes, germination success of in cooler temperate forests increases on host aspects oriented toward the sun (Taylor and Burns 2016). Within a forest, microsite differences (of epiphytic host trees) exist at many different spatial scales: within a single branch; between branches at different heights of the tree; between trees of different architecture; and within stands of differing topography and aspects. (Nadkarni et al. 2001). However, in tree community, slope aspect has no significant effect to stem density and species richness of trees based on study in a tropical rainforest of Amazon (Laurance et al. 2010). Those finding is similar with this study. There was no significant effect of host tree aspect on epiphytic orchids abundance, species richness and diversity. Seemingly, both species richness of trees and epiphytic orchids inhabit the trees are not significantly affected by slope aspect.

There was a positive correlation between abundance of orchid and other vascular epiphytes in zone 4 and zone 5. Ecological theory predicts that plants in stressful environments will show more positive than negative interactions between them (Bertness and Callaway 1994, Zotz 2016). Other epiphytes can facilitate the establishment and survival of epiphytic orchids seed by improving the anchorage and by causing more reliable water supply during germination (Wyse and Burns 2011). In the crown layer, orchids share habitat with mosses, lichens and ferns and often clumped on the same location. This would imply that there would not be serious competition for space and nutrient between orchids and other vascular epiphytes in the middle and outer-crown. In addition, other vascular epiphytes may act as 'island' and facilitate the establishment of orchid as the bryophytes did. This kind of interaction was recorded by Wallace (1981), ferns such as *Drynaria* or *Platycerium* established on a bare bark, with increased size and accumulation of organic material, these ferns provide suitable substrate for the germination of epiphytic orchid like *Cymbidium* sp. (Zotz 2016).

Management strategy for orchids conservation in study site

Applying SWOT analyses provides a good overview and makes it easy to pinpoint important problem areas (Rauch 2007). SWOT analysis helped us to understand the factors (both internal and external) which would affect the forest management, local resident life, and orchids and forest sustainability at the study site where the PHBM program is implemented in West Java Province. We now understood that the PHBM program had important role to reduce illegal and destructive forest utilization. On the other hand, we also understood that the PHBM program might negatively affect the terrestrial orchid species. Forest floor clearance is the major threat for terrestrial orchid conservation besides collecting the wild orchid species (Swarts and Dixon 2009). At the study site, in order to plant coffee trees and crops under the PHBM program, farmer cleared the forest floor including some understory trees (Figure 6.3). Not only affecting the terrestrial orchids, research by Hundera et al. (2013) in Ethiopia suggested the intensification of under shaded coffee plantation can reduce the epiphytic orchid species richness by reducing the density of trees and crown cover.

None of the terrestrial and epiphytic orchids were considered as important or charismatic species at the study site by SWOT analysis. However, we cannot let those species extinct only because they are common species. Conservation of common species is needed to ensure that they do not become uncommon or rare and thus can maintain their key ecological and functional roles in an ecosystem (Gaston 2010; Lindenmayer et al. 2011). By conserving epiphytic orchid, it will lead to the conservation of its host tree species. For example, as the dominant tree species in study site *S. wallichii* needs to be conserved as it both ecologically and economically important. Beside as the most preferable host tree for epiphytic orchid in the study site, *S. wallichii* has a wide range of uses. This species is traded as commercial timber, good source of firewood, the bark is used for dying and as a source of tannins and the flowers are used medicinally (Oldfield 2018).

Based on the SWOT analysis, we proposed strategic management. All the strategies that were proposed have not been implemented yet. However, these strategies can become an alternative for forest management in this area. We suggest expanding the area of the PHBM program to increase the number of local residents involved so that they would be benefited by the program. The income of local residents is mostly low and depends on the forest for fulfilling daily needs. Increasing the number of local people who are involved in the PHBM program will lead income for more number of households. Local people may be interested in conserving biodiversity only if certain rights to use lands and forests are allocated to them (Harada 2003). Where local people are interested in the conservation and traditional use of their lands, resources, and so forth, on condition that their fundamental human rights are respected, conflicts do not arise between the people's rights and interests, and the objectives of protected areas (IUCN 2000). However, we also suggest considering about avoiding destructive forest floor clearing that will affect negatively the population of terrestrial orchid and other native plant species.

The area of PHBM program can also be used for ecotourism together with coffee plantation. The natural orchid habitat with many epiphytic species can attract tourist to this area. Such ecotourism can bring lots of benefit to rural zones. Ecotourism in this area may also help to preserve local and traditional value of Sundanese people as part of tourist attraction. Rural tourism will cause the development of social and economic aspect of a village in long terms (Mahmoudi et al. 2011). With ecotourism, the local resident dependency on exploitative forest resources utilization may be controlled.

Several strategies were proposed to optimize the strengths and the opportunities for the purpose of overcoming the weaknesses and of avoiding the threats. These results may help the forest managers to analyze the problems in the PHBM program implementation for orchids and forest sustainability. The proposed strategies can become an alternative solution for further research on the PHBM program implementation in the study site.

Conclusion

Forty *Schima wallichi* trees host as many as 39 species and 1731 of epiphytic orchid in the study site. Orchid abundance and species richness were not significantly different among three crown zones. However, epiphytic orchids were more abundant in the crown zones than in the trunk zone. Tree size (DBH) and the number of branches positively affected orchid abundance and species richness in a host tree. Orchids were correlated positively in number with other vascular epiphytic plants at mid-crown (zone 4) and outer-crown (zone 5). Density of surrounding trees affected the number of orchids negatively. *S. wallichii* trees are essential to epiphytic orchid community because they develop many branches for epiphytic orchids to colonize. Preserving the large crowned *S. wallichii* with low density of surrounding trees is effective for conservation of epiphytic orchids.

The problems to which montane forests in West Java have been exposed were forest conversion into coffee plantation, illegal logging, and illegal collecting of valuable plants including orchids despite (the fact that) the forest status is mostly ‘protected forest’. Strategic management is needed to solve these problems. This thesis explores internal and external factors by SWOT analysis to formulate management strategies. From the SWOT analysis, several strategies were proposed to optimize the strengths and opportunities for the purpose of overcoming the weaknesses and to avoid the threats. Consequently, the proposed strategies can be an alternative for stakeholder to manage this forest sustainably not only for local residents but also for the epiphytic orchid and their hosts.

Figures

Figure 6.1 *Coelogyne miniata,* the most abundant epiphytic orchid species in the study site.

Figure 6.2 Density of trees surrounded the host tree affected the epiphytic orchid abundance negatively because trees surrounded the host tree shaded and blocked the required sun light for epiphytic orchids to grow.

Figure 6.3 Forest floor was cleared and planted with coffee and crop. This action can threat the sustainability of plants grown on the forest floor including the terrestrial orchids.

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