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Tree species diversity adapted to *Pinus merkusii* forests in Gunung Ciremai National Park, West Java, Indonesia

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Abstract. *Supartono T, Adhya I, Kosasih D, Wildani W. 2023. Tree species diversity adapted to* Pinus merkusii *forests in Gunung Ciremai National Park, West Java, Indonesia. Biodiversitas 24: 4314-4323.* One of the challenges faced in rehabilitating pine forests in conservation areas is the limited information on plant species capable of adapting to these ecosystems. This study aimed to analyze the diversity of tree species that grow and adapt to pine forests and the relationship of natural forests with the vegetation characteristics of pine forests. The research was conducted in pine forests bordering natural forests and far from natural forests using the sample plot method. The study recorded 44 species from 27 families of seedlings, 46 species from 21 families of saplings, 25 species from 18 families of poles, and 24 species from 17 families of trees. Accumulation of species from all growth stages recorded 83 species (76 local species and 7 cultivated species) from 39 families. Based on the species accumulation curve, pine forests adjacent to natural forests have more species than those far from natural forests. Individual and family density in pine forests adjacent to natural forests were also higher than the density of these two variables in pine forests far from natural forests. Furthermore, both the pine forest adjacent to the natural forest and that far from the natural forest, each has its own species peculiarities. The results indicate that the existence of natural forests has an important role as a source of biodiversity for the surrounding ecosystem. As an implication of this study, species that can grow to the level of poles and trees can be recommended as rehabilitation plants in the *Pinus merkusii* Jungh. & de Vriese forests in Gunung Ciremai National Park, Indonesia because pine is not a local species and the allelopathy it releases can reduce plant diversity.

Keywords: Adaptation, conservation, national park, *Pinus merkusii*, rehabilitation species

INTRODUCTION

National Park is a conservation area to maintain ecosystem authenticity (Yang et al. 2021) and provide environmental services (Sæþórsdóttir et al. 2022; Budiman et al. 2023). However, several national parks are experiencing degradation due to various factors (Deni et al. 2019; Clarke 2020). *Taman Nasional Gunung Ciremai* (TNGC) in Indonesia one of the national parks that experienced changes in several places. The changes occurred from a natural to *Pinus merkusii* forest. The replacement was made by Perum Perhutani KPH Kuningan when Gunung Ciremai functioned as a production forest. The pinus is not a local TNGC even though it is naturally distributed in Sumatra Island in Indonesia (Imanuddin et al. 2020). Meanwhile, the purpose of changing the function is to maintain local species and the authenticity of the ecosystem. The conversion of a forest ecosystem, including into a pine forest, has reduced biodiversity (Perry et al. 2016; Uribe et al. 2021; Semenchuk et al. 2022). Pine forests, referring to other cases, have caused water availability problems because this species consumes a lot of water than other types (Pramono et al. 2017). Therefore, efforts to restore the ecosystem need to do to increase ecosystem services and local species populations. However, logging cannot be carried out in theconservation area. Therefore, the recovery is by enriching and increasing the population of local species. The types of plants used are those that can adapt to pine forests. This is because the pine produces allelopathy (Santonja et al. 2019), which can inhibit the growth of other species (Bertolacci et al. 2018). One way to find out which species are adaptable is to identify the species that grow naturally down to the level of poles and trees in the pine forest. Local species that can grow to the level of poles and trees are considered species that have been able to adapt to the pine forests.

Manypublications are related to pine forest ecosystems with various themes (Fan et al. 2021; Lázaro-Lobo et al. 2022; Tomback et al. 2022; Vázquez-Veloso et al. 2022). Specifically related to biodiversity in pine forests, several researchers who have conducted research include Wang et al. (2021) in the *P. massoniana* forest in the Southeastern region of China, Randriambanona et al. (2019) in the *P. patula* forest in Madagascar, Li et al. (2020) in the *P. yunnanensis* forest in Yunan Province, China, Trujillo-Miranda et al. (2021) in a forest of *P. patula* in Southern Mexico, Stokes et al. (2010) in the *P. palustris* forest in Northeast Alabama, Becerra and Simonetti (2020) in the *P. radiata* forest in Chile, and Sukhbaatar et al. (2018) in the forests of *P. sylvestris* in the Northern Mongolia region. Those are examples of studies on the diversity of tree species in pine forests. However, these studies were not conducted in *P. merkusii* forests.

The publication -on the diversity of trees adapted to *P. merkusii* forests is limited. However,the publications are generally related to resin production (Hadiyane et al. 2015; Wijayanto et al. 2019; Indrajaya 2020; Sukarno et al. 2020; Mukhlisa and Dwiyanti 2021; Alam et al. 2023; Samis et al. 2023). Meanwhile, several publications related to tree diversity are by Siswo et al. (2019), Natalia et al. (2020), and Itawamerni et al. (2021). Furthermore, Supartono et al. (2022) conducted research in the *P. merkusii* forest in the TNGC; this research was only carried out in one place far from natural forest. In TNGC, there are also pine forests bordering natural forests. In addition, research of tree species diversity adapted to pine forests based on distance from natural forests is still difficult to find.

In this regard, the purpose of this study was to analyze the diversity of tree species that can grow and adapt to pine forests, and the relationship between the presence of natural forests and vegetation characteristics in pine forests. Furthermore, the results of this study are also expected to be considered in selecting species for restoring *P. merkusii* forests in TNGC and other protected areas. The restoration is important to maintain biodiversity and environmental services (Wan et al. 2020) including water availability needed by the community. Therefore, the implementation of this study is not only improtant for biodiversity but also for the community.

MATERIALS AND METHODS

Study area

The research was conducted in two locations in Gunung Ciremai National Park (TNGC) forest area of West Java Province, Indonesia. The first location is adjacent to the natural forest, and the second is far from the natural forest (Figure 1). The land cover for both locations is old pine forest planted around the early 1990s. This first location is the Karangsari Research Station, managed by the Faculty of Forestry and Environment, Universitas Kuningan, Indonesia in collaboration with the Kuningan Region I National Park Management Section, TNGC.

Procedures

The tools and materials needed for this research included writing tools, a hip chain to measure the length of the observation path, a camera to document tree species that had not yet been identified, and a machete to open pathways of sample plots when collecting data. The data type collected included the name of the plant species and the number of individuals of each species for the growth rate of seedlings and saplings, as well as the name of the species and stem diameter at breast height for the growth rate of poles and trees (Soerianegara and Indrawan 2005).

Data was collected by sampling with sample plot sizes following the Gentry (1982) method, namely 2 m x 50 m. Furthermore, using this method, the researcher walked toward the observation path in the middle of the sample plots and recorded all species and individuals for the growth rates of seedlings, saplings, poles, and trees. Thus, all growth rates are collected in the same grid. Species with unknown scientific names were photographed using a camera, then submitted to plant taxonomists from Botanical Lab. at The Directorate of Scientific Collection Management of BRIN, formerly known as LIPI, to be identified.

Furthermore, one sample plot with another was made continuously, formed an elongated observation path, and was placed perpendicular to the contour lines. In pine forests adjacent to natural forests, the starting point of the sample plots was at the edge of the patrol road. It reached the natural forest boundary for each observation route, so the number of sample plots varied. The distance between observation paths also varied according to ease of accessibility because many research locations are steep and cliffs. In addition, sample plots were made starting from the outermost part of the pine stand in a pine forest far from the natural forests. The number of sample plots on each route and the distance between lanes also varied due to accessibility, as in a pine forest bordering a natural forest. The total sample plots in pine forests bordering natural forests were 43, while the total sample plots in locations far from natural forests were 88. Thus, the total number of sample plots at both types of locations was 131 plots.

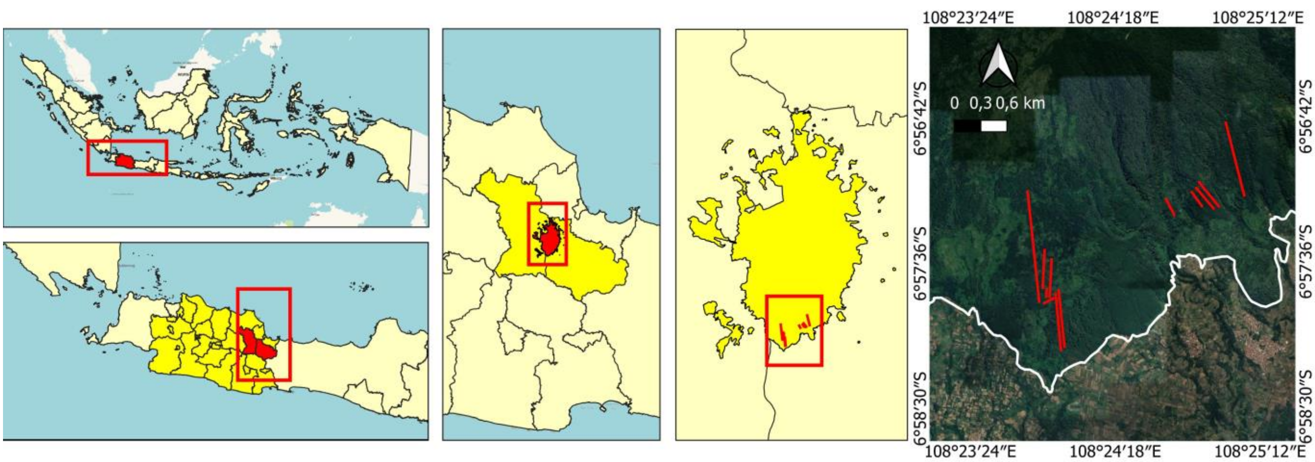

Figure 1. Research locations. A. Map of the *Taman Nasional Gunung Ciremai* area (West Java, Indonesia). B. The position of the data collection path. The red lines are observation paths placed in pine forests far from natural forests, while the black lines are observation paths in pine forests adjacent to natural forests

Data analysis

Vegetation data analysis was carried out descriptively (Mustari and Pasaribu 2019). The data analyzed includes density (ind/ha), frequency, dominance (m^2/ha), relative density, relative frequency, relative dominance, and important value index (Soerianegara and Indrawan 2005), with the following formula:

Density (ind/ha)
Ki = number of individuals of type i / total area of sample plots

Dominance (m^2/ha)
Di = area of the base of type i / total area of the sample plot

Relative density (%)
KR = (density of i-th species / total density of all species) x 100%

Relative dominance (%)
DR = (dominance of i-th species / total dominance of all species) x 100%

The Important Value Index (IVI)
The Important Value Index (IVI) of seedlings and saplings = FR + KR
The Important Value Index (IVI) of poles and trees = FR + KR + DR

Species diversity data were analyzed by accumulating all the species found in the sample plots and constructing a relationship curve between the number of plots and the number of species accumulated using microsoft excel. On this curve, the X-axis is for the number of tiles created, and the Y-axis is for the number of types accumulated. Furthermore, to determine the relationship between the presence of natural forests and the condition of the vegetation in pine stands, a comparison of several variables was carried out between pine forests adjacent to natural forests and pine forests far from natural forests. The variables that were compared were species diversity and individual density for each growth stage. The Simpson index for each growth rate is used in this analysis (Magurran 2003). Correspondence analysis (Costa et al. 2018) was also used to identify plant species that were the difference between pine forests adjacent to natural forests and far from natural forests.

RESULTS AND DISCUSSION

Species diversity

Research has recorded as many as 542 individuals from 83 species and 39 families of all growth levels. Based on the growth rate of these species; there are 44 species from 27 families for seedling growth rate, 46 species from 21 families for saplings, 25 species from 18 families for poles, and 24 species from 17 families for trees. Most of these species are from the pioneer tree groups. The number of species resulting from this study was more than those from the study by Supartono et al. (2022), who obtained 23 species. The difference is due to differences in the number of sample plots; This study was conducted on a larger number of sample plots than that of Supartono et al (2022). In addition, in the Wanagama I forest of Gunung Kidul, as many as 33 species of plants live in pine stands, but it is not stated how many species come from groups of trees (Widodo et al. 2010). Furthermore, the number of species at the study site is higher than those on the forest's edge, which is also part of the TNGC, namely 30 species from 22 families (Iskandar et al. 2021). These results indicate that the species diversity in the *P. merkusii* forest is still higher than the number of species in the secondary forest on the edge of the TNGC. Moreover, previous studies on various types of land cover in the TNGC have recorded as many as 94 tree species (Hidayat et al. 2022); this number is higher than in the study location. Thus, the results of this study and previous studies have provided information that many factors, including converted land from natural to plantation forests, influence the level of biodiversity in that place.

Pine is a type of plant that secrete substances to inhibit the growth of other types for its survival (Anwar et al. 2019). The presence of these substances causes only certain species to be able to grow under pine stands. This study's results indicate that 83 plant species can adapt to pine stands.

The research obtained as many as 7 types of cultivated plants from 83 species recorded, so 76 species were classified as local species. These types are African wood (*Maesopsis eminii*), avocado (*Persea americana*), mahogany (*Sweitenia macrophylla*), suren (*Toona sureni*), gmelina (*Gmelina arborea*), jackfruit (*Artocarpus heterophyllus*), and manglid (*Michelia velutina*). *M. eminii* and *P. americana* were found at the seedling to tree levels; *S. macrophylla*, *T. sureni*, and *G. arborea* were found at the tree level; *M. velutina* was found at the sapling to tree levels; and *A. heterophyllus* was found at the sapling and tree levels. There are many types of cultivated plants because the pine forest were originally included as production forests, and these types were introduced (Gunawan 2015) as intercrops or agroforestry plants. Of the cultivated species, *M. eminii* has the potential to become an invasive species (Epila et al. 2017; Handayani and Hidayati 2020); therefore, its presence in TNGC must be controlled. The presence of invasive species in an ecosystem can reduce plant diversity (Solfiyeni et al. 2022). The *M. eminii* produces fruit all year round, whose seeds can be dispersed by animals, and has the ability to grow well in new environments with a variety of conditions (Epila et al. 2017).

Dominance

Data analysis has also calculated the importance value index for each species to determine the dominant species in the pine forest. The research has shown that the species that dominate the growth rate of seedlings are *Macaranga tanarius*, *Oreocnide rubescens*, and *Litsea umbellata*; at the sapling level are *O. rubescens*, *Ficus fistulosa*, and *F. ribes*; at pole level are *F. fistulosa*, *M. velutina*, and *O. rubescens*; and at the tree level were *P. americana*, *M.*

tanarius, and *Trema cannabina* (Table 1). Previous research on pine forests at different locations in TNGC obtained results that the dominant species for the seedling stage were *Trevesia sundaica*, *Elaeocarpus stipularis*, and *F. fistulosa*; for the sapling stage were *T. sundaica*, *E. stipularis*, and *F. ribes;* for the pole level were *T. sundaica*, *F. fistulosa*, and *S. macrophylla* (Supartono et al. 2022). In the Watujali and Silengkong Kebumen pine forests, the species that dominate other than pine are *Casia seamea*, *Laportea sinuata*, and *F. septica* (Siswo et al. 2019). Other studies stated that *Coffea robusta*, *Eugenia cuprea*, and *Calliandra calothyrsus* were common species found in degraded areas in TNGC (Gunawan 2015). Based on the observations in the field, *C. robusta* and *C. calothyrsus* were often found at the study site, but were not recorded. This is because the recording is focused on pioneer tree species, from the growth stage of the seedlings to the trees. The planting of this type of coffee was carried out when Perum Perhutani still managed it. Coffee planting under *P. merkusii* stands is commonly carried out by Perum Perhutani through an agroforestry system, as is also done in the Rancakalong location, Sumedang District (Kinasih et al. 2016) and Cilengkrang, Bandung District (Iskandar et al. 2018).

The most common species were from the Laurace and Moraceae families, with 13 species and 9 species, respectively. The most common total individuals were from Moraceae and Urticaceae, with 107 and 96 individuals, respectively. Individuals from the Lauraceae family are also among the most common individuals (Table 2).

The results of this study are also in line with the results of research by Itawarnemi et al. (2021), where Lauraceae and Moraceae are the families that dominate the *P. merkusii* Janto forest, Aceh Besar, after Anacardiaceae and Sterculiaceae. Lauraceae is a typical tropical rainforest plant (Kostermans 1957) with many species; for example, in Taiwan, it can reach up to 76 species and is often found at 1,500 meters above sea level (Sheu et al. 2020). Moraceae is a plant widely distributed in tropical and subtropical climates and has more than 1000 species (Somashekhar et al. 2018).

Table 2. List of 15 families of tree species that have a large number of individuals and a large number of species

Families	Number of species	Number of individuals
Moraceae	9	107
Urticaceae	5	96
Lauraceae	13	83
Euphorbiaceae	6	76
Myrtaceae	3	34
Malvaceae	3	21
Magnoliaceae	1	14
Rhamnaceae	1	14
Proteaceae	2	13
Meliaceae	3	10
Canabaceae	1	8
Araliaceae	1	7
Fabaceae	6	7
Melastomataceae	1	7
Phyllanthaceae	2	6

Table 1. List of types of growth rates of seedlings, saplings, poles, and trees that have the highest IVI 5 in the *Pinus merkusii* forest in Gunung Ciremai National Park, Indonesia

Scientific name	Family	Plot	Obs.	Freq.	D (ind/ha)	IVI (%)
Seedling						
Macaranga tanarius	Euphorbiaceae	20	38	0.15	29.01	30.27
Oreocnide rubescens	Urticaceae	11	28	0.08	21.37	19.76
Litsea umbellata	Lauraceae	13	23	0.10	17.56	18.93
Ficus ribes	Moraceae	12	21	0.09	16.03	17.37
Ficus fistulosa	Moraceae	11	15	0.08	11.45	14.06
Sapling						
Oreocnide rubescens	Urticaceae	17	51	0.13	38.93	42.71
Ficus fistulosa	Moraceae	12	18	0.09	13.74	20.20
Ficus ribes	Moraceae	9	12	0.07	9.16	14.32
Macaranga tanarius	Euphorbiaceae	9	11	0.07	8.40	13.77
Litsea umbellata	Lauraceae	6	10	0.05	7.63	10.65
Pole						
Ficus fistulosa	Moraceae	10	14	0.08	10.69	45.38
Michelia velutina	Magnoliaceae	8	10	0.06	7.63	36.21
Oreocnide rubescens	Urticaceae	7	9	0.05	6.87	28.88
Macaranga tanarius	Euphorbiaceae	5	6	0.04	4.58	20.35
Ficus grossularioides	Moraceae	5	5	0.04	3.82	19.88
Tree						
Persea americana	Lauraceae	8	9	0.06	6.87	51.39
Macaranga tanarius	Euphorbiaceae	5	5	0.04	3.82	28.73
Trema cannabina	Canabiaceae	3	4	0.02	3.05	25.65
Syzygium sp.	Myrtaceae	3	3	0.02	2.29	19.70
Ficus sp.1	Moraceae	1	1	0.01	0.76	18.09

In the research by Wang et al. (2021) at five locations of *P. massoniana* stands in Hetian Town, China, the dominating families were Theacea, Fabaceae, Rosaceae, and Hamamelidaceae. In the *P. patula* forest in Madagascar, the species that dominates besides pine is the Myrtaceae family (Randriambanona et al. 2019). This study included the total number of individuals from the Myrtacea family in the 5 most common families. The comparison of the number of families between pine forests adjacent to natural forest and far from natural forest for growth rates of seedlings, saplings, poles and trees can be seen in Table 5 along with their explanations.

The relations of the existence of natural forest and vegetation characteristics

This research has recorded 45 species of plants (from 23 families), from seedlings to trees in pine forests bordering natural forests and 48 species (from 27 families) in pine forests far from natural forests. By constructing a relationship curve between the number of species and the number of sample plots (Deng et al. 2015), where the X-axis is the number of observation plots, and the Y-axis is the accumulation of species, the curve formed for pine forests bordering natural forests has a higher slope, higher than the curve for pine forest far away from the natural forest (Figure 2). At least two pieces of information can be obtained from the curve formed in Figure 2. First, the number of species in the two locations can increase when the number of sample plots is added. Second, the number of species in pine forests adjacent to natural forests is predicted to be higher than those in pine forests far from natural forests. An overview of the species that predominate in pine forests for each growth stage is presented in Table 1 along with their explanations.

The results of this study indicate that the presence of natural forests positively influences plant diversity in the surrounding ecosystems. In the theory of island biogeography (MacArthur and Wilson 1967), the existence of natural forests acts as the main island, and pine forests can act as the surrounding islands; the main island is a source of biodiversity. According to this theory, biodiversity on islands close to natural forests will be higher than on islands far from natural forests (Matthews et al. 2005). Thus, this study's results align with the theory of the island's biogeography, where pine forests that are close to natural forests have a higher diversity of tree species compared to pine forests that are far from natural forests. The description also provides information about the importance of natural forests as a source of biodiversity.

In this study, the number of sample plots in pine forests far from the natural forest was more than the number of sample plots made in pine forests that were close to the natural forest due to ease of access. Therefore, it is necessary to standardize the total area of sample plots for the number of individuals (ind/ha) and the number of sample plots for the number of species (species/plot), and the number of families (family/plot) so that comparisons can be made between the two locations. After standardization, the individual density values in pine forests adjacent to natural forests were greater than those far from natural forests for all growth stages (Figure 3) and significantly different ($P<0.001$ for seedlings and saplings and $P=0.025$ for poles), except at the tree level ($P=0.672$). The conditions were the same for species density (Figure 4) and family density (Figure 5); both variables have a greater value in forests adjacent to natural forests than those far from natural forests. Tests of mean differentials on species densities yielded significant differences at both the seedling and sapling levels ($P<0.001$) and poles ($P=0.032$), whereas at the tree level they were not significantly different ($P=0.642$). Likewise for family density, the levels of seedlings and saplings ($P<0.001$) and poles ($P=0.038$) were significantly different, except for tree height ($P=0.612$). This study aligns with the results of Magnago et al. (2015); the closer a place is to a large natural forest, the higher the species diversity, especially local species. Also, research by Al-Namazi and Bonser (2022) stated the farther from the source area, the lower the individual density. That also shows that the presence of natural forest has a positive effect on individual density and species diversity. The species found from the two types of pine forest locations have different important index values and these indices are used to determine the dominant species (Tables 3, 4, 5, and 6).

Locations close to natural forest will have a greater chance of getting the distribution of species compared to locations far away. Wind can aid species dispersal (Wan et al. 2017; Nazareno et al. 2021) by flying very small seeds and discarded wildlife (Chen et al. 2017; Chandru et al. 2020) through the poop. The distribution model determines the distance of seeds that animals can spread (Chen et al. 2017). Other studies have also shown that seed dispersal distance is affected by the degree of habitat fragmentation (Nield et al. 2020). In the case of gibbon dispersal, the average distance of seeds that can be spread is about 223.9 m from the parent tree (Adyn et al. 2022). These descriptions are one of the reasons the number of species and the density of individual trees and their young are higher in pine forests adjacent to natural forests than those far from natural forests.

Data analysis has also calculated the Simpson Index value. The index value for all growth rates in pine forests adjacent to natural forests tends to be greater than in pine forests far from natural forests (Figure 6). The value of the Simpson Index relates to the number of individuals of each species, the more uneven the number of individuals for each species the greater the value of the index (Magurran 2003). These results show that the number of individuals of each species in pine forests adjacent to natural forests varies more than in pine forests far from natural forests. Because the existence of species in an area is influenced by various environmental factors (Chen et al. 2014; Yilmaz et al. 2017), then this study also shows that environmental conditions in locations bordering natural forests are also more diverse. Furthermore, these diverse conditions may be related to its position close to natural forests.

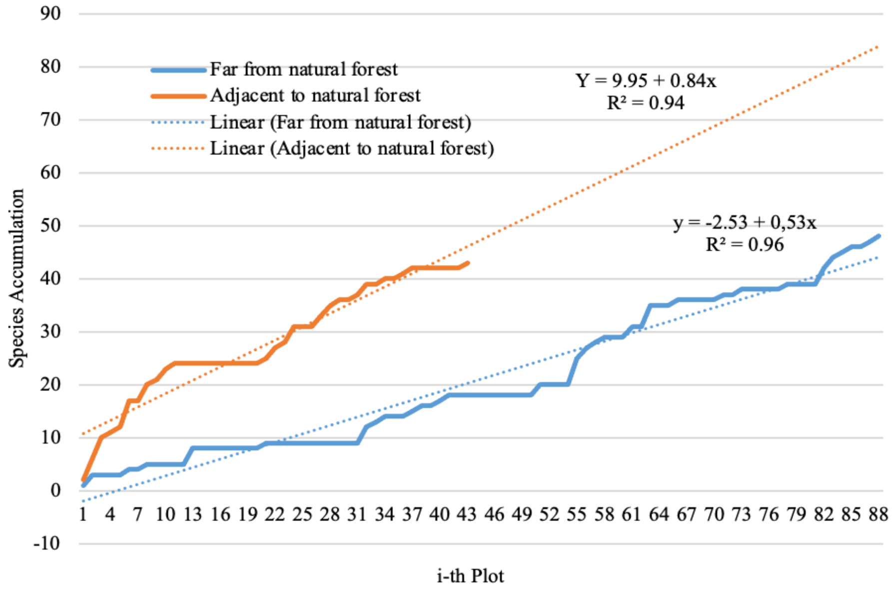

Figure 2. The relationship curve between species accumulation and the number of sample plots

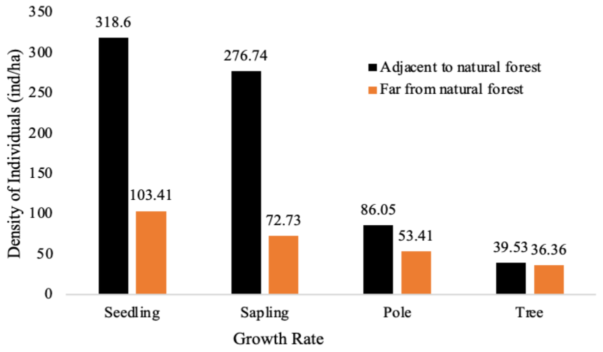

Figure 3. Comparison of tree density (ind/ha) between pine forest adjacent to natural forest and pine forest far away from the natural forest for the growth rate of seedlings, saplings, poles, and trees

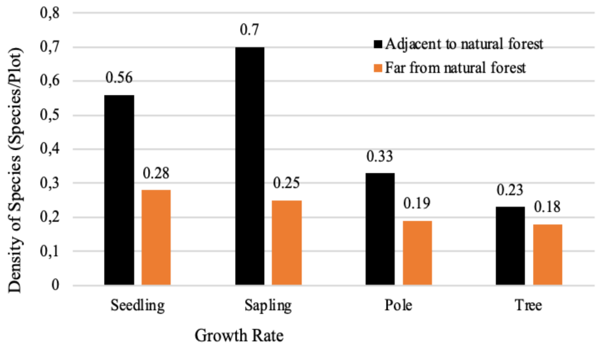

Figure 4. Comparison of species density (species/plots) between pine forests adjacent to natural forests and pine forests far away from the natural forest for growth rates of seedlings, saplings, poles, and trees

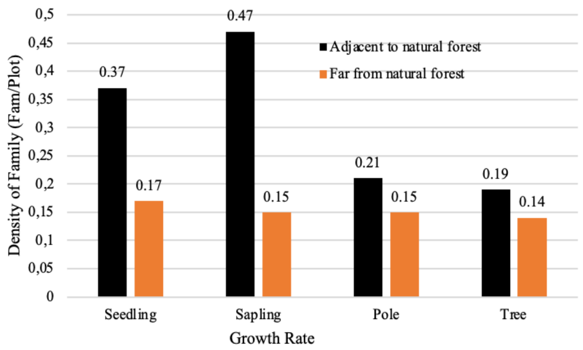

Figure 5. Comparison of family densities (families/plots) between pine forests adjacent to natural forests and pine forests far away from the natural forest for growth rates of seedlings, saplings, poles, and trees

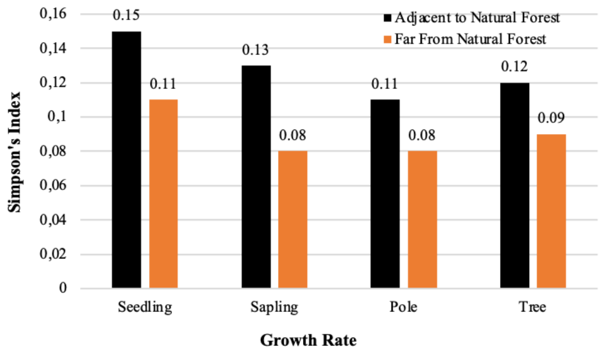

Figure 6. Simpson index for growth rates of seedlings, sapling, poles, and trees in pine forests adjacent to natural forests and far from natural forests

The plant species at the seedling level that dominate the pine forest close to the natural forest are *M. tanarius*, *O. rubescens*, and *F. ribes*. Meanwhile, the species that dominated the pine forest away from the natural forest for the same growth rate were *L. umbellata*, *Syzygium* sp., and *F. fistulosa* (Table 3).

The sapling-level plant species that dominate the pine forest close to the natural forest are *O. rubescens*, *M. tanarius*, and *F. fistulosa*. Meanwhile, the species dominating the pine forest away from the natural forest for the same growth rate were *L. umbellata*, *F. fistulosa*, and *O. rubescens* (Table 4).

The pole-level plant species that dominate the pine forest close to the natural forest are *F. fistulosa*, *O. rubescens*, and *M. tanarius*. Meanwhile, the species that predominated in pine forests far from natural forests for the same growth rate were *M. velutina*, *F. fistulosa*, and *P. americana* (Table 5).

The tree-level plant species that dominate the pine forest close to the natural forest are *M. tanarius*, *T. cannabina*, and *Ficus* sp. Meanwhile, for the same growth rate, the species that dominated the pine forests far from natural forests were *P. americana*, *Syzygium* sp., and *Hibiscus macrophyllus* (Table 6). This research also shows that the distance from natural forests indirectly affects the dominant plant species. For example, *P. americana*, which dominates pine forests far from natural forests, is the result of plantations. Pine forests far from natural forests are closer to settlements, while pine forests adjacent to natural forests are far from settlements. Therefore, people will choose locations closer to settlements to plant avocados compared to locations far away so that cultivated plants dominate locations far from natural forests. *M. eminii* dominates locations far from natural forests, presumably for the same reasons as *P. americana*.

Based on the results of this study, the genus *Ficus* was always found in both types of study sites, both for the growth rate of seedlings, saplings, poles, and trees. These *Ficus* generally belong to the dominating types. That shows the *Ficus* genus has a good adaptation to the pine forests level. Previous researchers also mentioned that *Ficus* can adapt to various climatic conditions (Polat and Caliskan 2008). The high adaptability of *Ficus* is due to its diverse growth forms, which can be trees, shrubs, climbers and scramblers, epiphytes, hemi-epiphytes, or lithophytic (Rønsted et al. 2008; Wijaya and Defiani 2021). Birds, bats, primates, and civets can assist *Ficus* in dispersing their seeds (Lomáscolo et al. 2010; Nakabayashi et al. 2019). These species, especially birds and bats, can explore quite far. It is also suspected that the cause of *Ficus* can be found in both research locations, in addition to the high ability to adapt.

Table 3. List of 10 seedling-plant species that have the largest IVI (%) in each pine forest adjacent to natural forest and that far from natural forest

Adjacent to natural forest			**Far from natural forest**		
Scientific name	**Family**	**IVI (%)**	**Scientific name**	**Family**	**IVI (%)**
Macaranga tanarius	Euphorbiaceae	50.76	*Litsea umbellata*	Lauraceae	44.68
Oreocnide rubescens	Urticaceae	34.19	*Syzygium* sp.	Myrtaceae	27.72
Ficus ribes	Moraceae	26.37	*Ficus fistulosa*	Moraceae	23.32
Microcos paniculata	Malvaceae	20.95	*Maesopsis eminii*	Rhamnaceae	17.75
Ficus fistulosa	Moraceae	6.88	*Memecylon myrsinoides*	Melastomataceae	13.66
Trevesia sundaica	Araliaceae	6.67	*Mallotus puniculatus*	Euphorbiaceae	8.09
Actinodaphne glomerata	Lauraceae	5.94	*Alangium rotundifolium*	Cornaceae	5.18
Dysoxylum densiflorum	Meliaceae	5.94	*Nothaphoebe umbellata*	Lauraceae	5.18
Ostodes paniculata	Euphorbiaceae	5.94	*Litsea angulata*	Lauraceae	5.18
Helicia sp.	Proteaceae	4.69	*Planchonella valida*	Lecythidaceae	5.18

Table 4. List of 10 sapling plant species that have the largest IVI (%) in each pine forest adjacent to natural forest and that far from natural forest

Adjacent to natural forest			**Far from natural forest**		
Scientific name	**Family**	**IVI (%)**	**Scientific name**	**Family**	**IVI (%)**
Oreocnide rubescens	Urticaceae	53.04	*Litsea umbellata*	Lauraceae	28.96
Macaranga tanarius	Euphorbiaceae	21.41	*Ficus fistulosa*	Moraceae	24.27
Ficus fistulosa	Moraceae	17.35	*Oreocnide rubescens*	Urticaceae	23.19
Ficus ribes	Moraceae	17.02	*Syzygium* sp.	Myrtaceae	15.14
Helicia sp.	Proteaceae	9.43	*Persea americana*	Lauraceae	12.92
Actinodaphne glomerata	Lauraceae	6.58	*Ficus ribes*	Moraceae	9.13
Ficus grossularioides	Moraceae	6.58	*Homalanthus populneus*	Euphorbiaceae	7.57
Ostodes paniculata	Euphorbiaceae	6.58	*Leucaena leucocephala*	Fabaceae	7.57
Neolitsea javanica	Lauraceae	5.55	*Michelia velutina*	Magnoliaceae	7.57
Actinodaphne macrophylla	Lauraceae	5.22	*Syzygium polyanthum*	Myrtaceae	7.57

Table 5. List of 10 pole plant species that have the largest IVI (%) in each pine forest adjacent to natural forest and that far from natural forest

Adjacent to natural forest			Far from natural forest		
Scientific name	**Family**	**IVI (%)**	**Scientific name**	**Family**	**IVI (%)**
Ficus fistulosa	Moraceae	62.64	*Michelia velutina*	Magnoliaceae	62.44
Oreocnide rubescens	Urticaceae	60.67	*Ficus fistulosa*	Moraceae	32.93
Macaranga tanarius	Euphorbiaceae	39.81	*Persea americana*	Lauraceae	31.89
Trema cannabina	Canabaceae	27.98	*Syzygium* sp.	Myrtaceae	28.67
Ficus sp.	Moraceae	25.38	*Ficus grossularioides*	Moraceae	28.35
Ficus ribes	Moraceae	13.74	*Ficus ribes*	Moraceae	19.54
Litsea angulata	Lauraceae	9.99	*Syzygium polyanthum*	Myrtaceae	15.30
Glochidion zeylanicum	Phyllanthaceae	9.38	*Hibiscus macrophyllus*	Malvaceae	14.46
Gmelina arborea	Verbenaceae	9.24	*Toona sureni*	Meliaceae	12.68
Saurauia blumeana	Actinidiaceae	8.82	*Pipturus argenteus*	Urticaceae	8.33

Table 6. List of 10 tree plant species that have the largest IVI (%) in each pine forest adjacent to natural forest and that far from natural forest

Adjacent to natural forest			Far from natural forest		
Scientific name	**Family**	**IVI (%)**	**Scientific name**	**Family**	**IVI (%)**
Macaranga tanarius	Euphorbiaceae	77.69	*Persea americana*	Lauraceae	82.71
Trema cannabina	Canabaceae	67.14	*Syzygium* sp.	Myrtaceae	31.96
Ficus sp.	Moraceae	43.90	*Hibiscus macrophyllus*	Malvaceae	22.33
Saurauia blumeana	Actinidiaceae	19.45	*Maesopsis eminii*	Rhamnaceae	20.72
Actinodaphne glomerata	Lauraceae	16.53	*Ficus grossularioides*	Moraceae	19.28
Gmelina arborea	Verbenaceae	15.98	*Swietenia marcophylla*	Meliaceae	16.67
Artocarpus heterophyllus	Moraceae	15.47	*Syzygium polyanthum*	Myrtaceae	16.55
Maesopsis eminii	Rhamnaceae	15.15	*Michelia velutina*	Magnoliaceae	16.47
Helicia sp.	Proteaceae	14.55	*Toona sureni*	Meliaceae	10.89
Unidentified	-	14.15	*Albizia lebbekoides*	Fabaceae	10.19

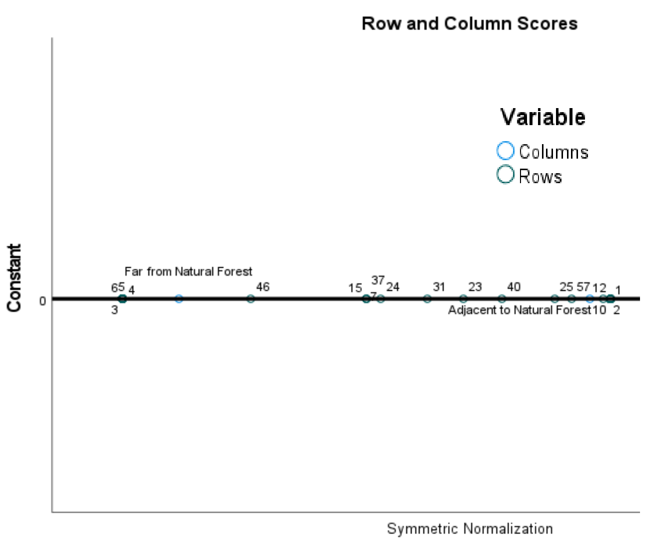

Figure 7. Correspondence analysis between pine forests adjacent to natural forests and pine forests far from natural forests based on plant species composition

Correspondence analysis has been carried out to determine the peculiarities of both types of pine forests based on species composition. As shown in Figure 7, typical species of pine forests far from natural forests are *Alangium rotundifolium* (number 3), *Albizia lebbekoides* (number 4), *Albizia procera* (number 5), and *Albizia* sp. (number 6). Meanwhile, typical species of pine forests bordering natural forests are *Actinodaphne glomerata* (number 1), *Actinodaphne macrophylla* (number 2), *Castanopsis argentea* (number 10), *Cinnamomum sintoc* (number 12), *Ficus ribes* (number 25), *Macaranga tanarius* (number 44), and *O. rubescens* (number 57). This research has not been able to answer the cause of the emergence of distinctive types for each of these pine forests. However, the presence of a species in a habitat is influenced by various factors such as geological, climatic, topographic, solar radiation, canopy density, altitude, slope gradient, surrounding population density, land use type, human activity, and other biotic (Chen et al. 2014; Yilmaz et al. 2017).

Conservation implications

TNGC is one of the conservation areas with a pine forest. Even though *P. merkusii*, which in the TNGC is an introduced species, is not allowed to be logged because it is in a conservation area. Therefore, to slowly restore pine forests that were previously natural forests to their original condition, efforts can be made to increase local species and populations of species. Local species proven to adapt to pine forests can be used for population addition and species enrichment. This study assumes that the species that adapt have been able to live up to the growth level of poles and trees in a pine forest. Both growth rates are considered mature and capable of producing offspring in the form of fruit production. From the results of this study, 28 local species could live up to the growth level of poles and trees. Of these species, the ten most common are *F. fistulosa*, *M. tanarius*, *O. rubescens*, *F. grossularioides*, *Syzygium* sp. *T. cannabina*, *F. ribes*, *H. macrophyllus*, *S. polyanthum*, and

Ficus sp. Thus, this study obtained 28 species that could be recommended for population addition and enrichment in pine forests, prioritizing the 10 most common species.

In conclusion, there were 76 local species capable of growing on *P. merkusii* forests. The diversity and individual density of local species occupying *P. merkusii* forests are related to the presence of natural forests. Hence, the presence of natural forests has an important role as a source of biodiversity for the surrounding ecosystem. Of the total species found, 28 are recommended for rehabilitating areas turned into *P. merkusii* forests. The follow-up research needed is effective cultivation techniques for each of the recommended species.

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REFERENCES

Adyn MF, Sibarani MC, Utoyo, Surya RA, Sedayu A. 2022. Role of siamang (*Symphalangus syndactylus*) as seed dispersal agent in a Sumatran lowland tropical forest. Biodiversitas 23 (4): 2101-2110. DOI: 10.13057/biodiv/d230445.

Alam AS, Rafiuddin, Rachman I, Pribadi H, Hamzari. 2023. Productivity of pinus sap (*Pinus merkusii*) in Uelincu Village, Pamona, Utara District, Poso District. J Survey Fish Sci 10 (3S): 920-928.

Al-Namazi AA, Bonser SP. 2022. Island biogeography, competition, and abiotic filtering together control species richness in habitat islands formed by nurse tree canopies in an arid environment. Commun Integr Biol 15 (1): 232-239. DOI: 10.1080/19420889.2022.2139471.

Anwar T, Ilyas N, Qureshi R, Munazir M, Rahim BZ, Qureshi H, Kousar R, Maqsood M, Abbas Q, Bhatti MI, Panni, MK. 2019. Allelopathic potential of *Pinus Roxburghii* needles against selected weeds of wheat crop. Appl Ecol Environ Res 17 (2): 1717-1739. DOI: 10.15666/aeer/1702_17171739.

Becerra PI, Simonetti JA. 2020. Native and exotic plant species diversity in forest fragments and forestry plantations of a coastal landscape of central Chile. Bosque 41 (2): 125-136. DOI: 10.4067/S0717-92002020000200125.

Bertolacci R, Meza G, Sandell S. 2018. Impact of pine allelopathy on seed germination. Purchase College J Ecol 2: 35-41.

Budiman H, Akhmaddhian S, Agustin D, Bhandari R. 2023. Tourism law enforcement in regional spatial planning and licensing perspectives. Unifikasi: Jurnal Ilmu Hukum 10 (1): 1-10. DOI: 10.25134/unifikasi.v10i1.4288. [Indonesian]

Chandru G, Pandiyan J, Durga V, Govindarajan M, Alharbi NS, Kadaikunnan S, Khaled JM, Panneerselvam C, Krishnappa K. 2020. Seed dispersal by ungulates in the point calimere wildlife sanctuary: A scientific and perspective analysis. Saudi J Biol Sci 27 (10): 2790-2797. DOI: 10.1016/j.sjbs.2020.06.042.

Chen Y, Wang Z, Xiang Z. 2017. Seed dispersal by primates. Biodivers Sci 25 (3): 325-331. DOI: 10.17520/biods.2016148.

Chen Y, Yang X, Yang Q, Li D, Long W, Luo W. 2014. Factors affecting the distribution pattern of wild plants with extremely small populations in Hainan Island, China. PLoS ONE 9 (5): e97751. DOI: 10.1371/journal.pone.0097751.

Clarke M. 2020. Trail Degredation in Cape Breton Highlands National Park: An Ecological Approach to Vegetation Restoration. [Thesis] Saint Mary's University, Halifax. [Canada]

Costa ALA, Brighenti CRG, Cirillo MA. 2018. A new approach to simple correspondence analysis with emphasis on the violation of the independence assumption of the levels of categorical variables. Acta Scientiarum Technol 40 (1): 34953. DOI: 10.4025/actascitechnol.v40i1.34953.

Deng C, Daley T, Smith AD. 2015. Applications of species accumulation curves in large-scale biological data analysis. Quant Biol 3 (3): 135-144. DOI: 10.1007/s40484-015-0049-7.

Deni, Adiwibowo S, Satria A, Kartodihardjo H. 2019. Alternative livelihood dilemmas and the degradation of protected areas: Power contestation and social-ecological interests in Gede Pangrango National Park. IOP Conf Ser Earth Environ Sci 285: 012001. DOI: 10.1088/1755-1315/285/1/012001.

Epila J, Verbeeck H, Otim-Epila T, Okullo P, Kearsley E, Steppe K. 2017. The ecology of Maesopsis eminii Engl. in tropical Africa. Afr J Ecol 55 (4): 679-692. DOI: 10.1111/aje.12408.

Fan Y, Zhang S, Lan Z, Lan Q. 2021. Possible causes for the differentiation of *Pinus yunnanensis* and *P. kesiya* var. *langbianensis* in Yunnan, China: Evidence from seed germination. For Ecol Manag 494: 119321. DOI: 10.1016/j.foreco.2021.119321.

Gentry AH. 1982. Patterns of Neotropical plant species diversity. Evol Biol 15: 1-85. DOI: 10.1007/978-1-4615-6968-8_1.

Gunawan H. 2015. Suksesi sekunder hutan terganggu bekas perambahan di Taman Nasional Gunung Ciremai, Jawa Barat. Pros Sem Nas Masy Biodiv Indon 1: 1591-1599. DOI: 10.13057/psnmbi/m010709. [Indonesian]

Hadiyane A, Sulistyawati E, Asharina WP, Dungani R. 2015. A study on production of resin from Pinus merkusii jungh. Et De vriese in the Bosscha observatory area, west Java-Indonesia. Asian J Plant Sci 14 (2): 89-93. DOI: 10.3923/ajps.2015.89.93,

Hidayat R, Marsono D, Susanto S, Sadono R. 2022. Komposisi dan struktur vegetasi hulu Daerah Aliran Sungai Cisanggarung, Taman Nasional Gunung Ciremai. Agrienvi 16 (2): 126-136. DOI: 10.36873/aev.v16i2.5553. [Indonesian]

Imanuddin R, Hidayat A, Rachmat HH, Turjaman M, Pratiwi, Nurfatriani F, Indrajaya Y, Susilowati A. 2020. Reforestation and sustainable management of Pinus merkusii forest plantation in Indonesia: A review. Forests 11: 1235. DOI: 10.3390/f11121235.

Indrajaya Y. 2020. Joint production of wood, resin, and carbon from pine plantation forest in Java. IOP Con Ser Earth Environ Sci 487: 012021. DOI: 10.1088/1755-1315/487/1/012021.

Iskandar BS, Iskandar J, Partasasmita R. 2018. Planting coffee and take care of forest: A case study on coffee cultivation in the forest carried out among people of Palintang, Highland of Bandung, West Java, Indonesia. Biodiversitas 19: 2183-2195. DOI: 10.13057/biodiv/d190626.

Iskandar SDH, Bramasta D, Peniwidiyanti, Kamala N, Basrowi M, Sulistijorini. 2021. Komposisi jenis dan struktur vegetasi tepi hutan, Taman Nasional Gunung Ciremai, Jawa Barat. Jurnal Sumberdaya Hayati 7 (1): 17-24. DOI: 10.29244/jsdh.7.1.17-24. [Indonesian]

Itawamerni H, Rasnovi S, Zumaidar, Z. 2021. Vegetation analysis and plant diversity in Pinus Jantho Forest (PJF) nature reserve, Aceh Besar. Jurnal Natural 21 (1): 23-28. DOI: 10.24815/jn.v21i1.18417.

Kinasih IDA, Cahyanto TRI, Widiana ANA, Nurbah D, Kurnia I, Julita UCU, Putra REKA. 2016. Soil invertebrate diversity in coffee-pine agroforestry system at Sumedang, West Java. Biodiversitas 17 (2): 473-478. DOI: 10.13057/biodiv/d170211.

Kostermans AJGH. 1957. Reinwardtia. Bulletin Du Jardin Botanique de Buitenzorg.

Lázaro-Lobo A, Ruiz-Benito P, Lara-Romero C, Castro-Díez P. 2022. Biotic, abiotic, and anthropogenic drivers of demographic performance of non-native Eucalyptus and Pinus species in forested areas of Spain. For Ecol Manag 510: 120111. DOI: 10.1016/j.foreco.2022.120111.

Li S, Huang X, Shen J, Xu F, Su J. 2020. Effects of plant diversity and soil properties on soil fungal community structure with secondary succession in the Pinus yunnanensis forest. Geoderma 379: 114646. DOI: 10.1016/j.geoderma.2020.114646.

Lomáscolo SB, Levey DJ, Kimball RT, Bolker BM, Alborn HT. 2010. Dispersers shape fruit diversity in Ficus (Moraceae). Proc Nat Acad Sci USA 107 (33): 14668-14672. DOI: 10.1073/pnas.1008773107.

MacArthur RH, Wilson EO. 1967. The Theory of Island Biogeography (REV-Revised). Princeton University Press, Princeton.

Magnago LFS, Magrach A, Laurance WF, Martins SV, Meira-Neto JAA, Simonelli M, Edwards DP. 2015. Would protecting tropical forest fragments provide carbon and biodiversity cobenefits under REDD+?. Glob Change Biol 21 (9): 3455-3468. DOI: 10.1111/gcb.12937.

Magurran AE. 2003. Measuring Biological Diversity. Blackwell Publishing, Australia.

Matthews JW, Tessene PA, Wiesbrook SM, Zercher BW. 2005. Effect of area and isolation on species richness and indices of Floristic Quality in Illinois, USA wetlands. Wetlands 25 (3): 607-615. DOI: 10.1672/0277-5212(2005)025[0607:EOAAIO]2.0.CO;2.

Mukhlisa AN, Dwiyanti AAR. 2021. Sustainable development strategy of pine resin in Bone District, South Sulawesi, Indonesia. E3S Web Conf 277: 1-5. DOI: 10.1051/e3sconf/202127705001.

Mustari AH, Pasaribu AF. 2019. Habitat characteristics and population of javan langur (*Trachypithecus auratus* E. Geoffroy Saint-Hilaire, 1812) In Leuweung Sancang Nature Reserve, Garut, West Java. Jurnal Wasian 6 (2): 77-88. DOI: 10.20886/jwas.v6i2.4816.

Nakabayashi M, Inoue Y, Ahmad AH, Izawa M. 2019. Limited directed seed dispersal in the canopy as one of the determinants of the low hemiepiphytic figs' recruitments in Bornean Rainforests. PLoS ONE 14 (6): e0217590. DOI: 10.1371/journal.pone.0217590.

Natalia K, Jumari, Murningsih. 2020. Struktur komposisi vegetasi hutan pinus di Kawasan Candi Gedong Songo, Kecamatan Bandungan, Kabupaten Semarang, Jawa Tengah. NICHE J Trop Biol 3 (2): 50-58. [Indonesian]

Nazareno AG, Knowles LL, Dick CW, Lohmann LG. 2021. By animal, water, or wind: Can dispersal mode predict genetic connectivity in riverine plant species? Front Plant Sci 12: 626405. DOI: 10.3389/fpls.2021.626405.

Nield AP, Nathan R, Enright NJ, Ladd PG, Perry GLW. 2020. The spatial complexity of seed movement: Animal-generated seed dispersal patterns in fragmented landscapes revealed by animal movement models. J Ecol 108: 687-701. DOI: 10.1111/1365-2745.13287.

Perry J, Lojka B, Ruiz LGQ, Van Damme P, Houška J, Cusimamani EF. 2016. How natural forest conversion affects insect biodiversity in the Peruvian Amazon: Can agroforestry help. Forests 7: 82. DOI: 10.3390/f7040082 .

Polat AA, Caliskan O. 2008. Fruit characteristics of table fig (Ficus carica) cultivars in subtropical climate conditions of the mediterranean region. New Zealand J Crop Hortic Sci 36 (2): 107-115. DOI: 10.1080/01140670809510226.

Pramono IB, Budiastuti MTS, Gunawan T, Wiryanto. 2017. Water yield analysis on area covered by pine forest at Kedungbulus Watershed Central Java, Indonesia. Intl J Adv Sci Eng Inf Technol 7 (3): 943-949. DOI: 10.18517/ijaseit.7.3.2442.

Randriambanona H, Randriamalala JR, Carrière SM. 2019. Native forest regeneration and vegetation dynamics in non-native *Pinus patula* tree plantations in Madagascar. For Ecol Manag 446: 20-28. DOI: 10.1016/j.foreco.2019.05.019.

Rønsted N, Weiblen GD, Savolainen V, Cook JM. 2008. Phylogeny, biogeography, and ecology of Ficus section Malvanthera (Moraceae). Mol Phylogenet Evol 48: 12-22. DOI: 10.1016/j.ympev.2008.04.005.

Sæþórsdóttir AD, Wendt M, Ólafsdóttir R. 2022. Tourism industry attitudes towards National Parks and Wilderness: A case study from the Icelandic Central Highlands. Land 11: 2066. DOI: 10.3390/land11112066.

Samis Y, Dahlan, Arlita T. 2023. Potensi produksi getah pinus (Pinus merkusii) pada kelas diameter batang berbeda menggunakan sistem koakan. Jurnal Ilmiah Mahasiswa Pertanian 8 (1): 665-672. DOI: 10.17969/jimfp.v8i1.23318. [Indonesian]

Santonja M, Bousquet-Mélou A, Greff S, Ormeño E, Fernandez C. 2019. Allelopathic effects of volatile organic compounds released from *Pinus halepensis* needles and roots. Ecol Evol 9: 8201-8213. DOI: 10.5061/dryad.s0b179p.

Semenchuk P, Plutzar C, Kastner T, Matej S, Bidoglio G, Erb KH, Essl F, Haber H, Wessely J, Krausmann F, Dullinger S. 2022. Relative effects of land conversion and land-use intensity on terrestrial vertebrate diversity. Nat Commun 13: 615. DOI: 10.1038/s41467-022-28245-4.

Sheu BH, Chou FS, Chang CK, Zhen YS, Lin WC, Chen W P. 2020. A study on species identification based on leaf contours of Taiwan Lauraceae and Fagaceae plants. 2nd IEEE Eurasia Conference on Biomedical Engineering, Healthcare and Sustainability. DOI: 10.1109/ECBIOS50299.2020.9203731.

Siswo, Yun CW, Abdiyani S. 2019. Assessing vegetation composition and the indicator species around water source areas in a pine forest plantation: A case study from Watujali and Silengkong Catchments, Kebumen, Indonesia. Forests 10: 825. DOI: 10.3390/f10100825.

Soerianegara I, Indrawan A. 2005. Ekologi Hutan Indonesia. Institut Pertanian Bogor, Bogor. [Indonesian]

Solfiyeni, Syamsuardi, Chairul, Mukhtar E. 2022. Impacts of invasive tree species *Bellucia pentamera* on plant diversity, microclimate and soil of secondary tropical forest in West Sumatra, Indonesia. Biodiversitas 23 (6): 3135-3146. DOI: 10.13057/biodiv/d230641.

Somashekhar M, Nayeem N, Sonnad B. 2018. A review on family Moraceae (Mulberry) with a focus on *Artocarpus* species. World J Pharm Pharm Sci 2 (5): 2614-2626.

Stokes TA, Samuelson LJ, Kush JS, Farris MG, Gilbert JC. 2010. Structure and diversity of longleaf pine (*Pinus palustris* Mill.) forest communities in the mountain longleaf national wildlife refuge, Northeastern Alabama. Nat Areas J 30 (2): 211-225. DOI: 10.3375/043.030.0208.

Sukarno A, Zairina A, Quarta Y, Kurniasari R, Sumardi S, Leksono AS. 2020. Yield and components of pine (*Pinus merkusii*) turpentine among age class differences tapping by borehole method. Indonesian J Environ Sustain Dev 11 (1): 2087-3522. DOI: 10.21776/ub.jpal.2020.011.01.07.

Sukhbaatar G, Suran B, Nachin B, Chultem D. 2018. Effects of scots pine (*Pinus sylvestris* L.) plantations on plant diversity in Northern Mongolia. Mongolian J Biol Sci 18 (1): 59-70. DOI: 10.22353/mjbs.2018.16.08.

Supartono T, Adhya I., Hendrayana Y, Kosasih D, Dahrun I. 2022. Tree species growing on Pinus merkusii stands at Karangsari Research Station, Gunung Ciremai National Park, West Java. Proceedings of the 2nd Universitas Kuningan International Conference on System, Engineering, and Technology, UNISET 2021, 2 December 2021, Kuningan. DOI: 10.4108/eai.2-12-2021.2320299.

Tomback DF, Keane RE, Schoettle AW, Sniezko RA, Jenkins MB, Nelson CR, Bower AD, DeMastus CR, Guiberson E, Krakowski J, Murray MP, Pansing ER, Shamhart J. 2022. Tamm review: Current and recommended management practices for the restoration of whitebark pine (*Pinus albicaulis* Engelm.), an imperiled high-elevation Western North American forest tree. For Ecol Manag 522: 119929. DOI: 10.1016/j.foreco.2021.119929.

Trujillo-Miranda AL, Toledo-Aceves T, López-Barrera F, Günter S. 2021. Tree diversity and timber productivity in planted forests: *Pinus patula* versus mixed cloud forest species. New For 52 (2): 177-195. DOI: 10.1007/s11056-020-09787-1.

Uribe SV, García N, Estades CF. 2021. Effect of land use history on biodiversity of pine plantations. Front Ecol Evol 9: 609627. DOI: 10.3389/fevo.2021.609627.

Vázquez-Veloso A, Dejene T, Oria-de-Rueda JA, Guijarro M, Hernando C, Espinosa J, Madrigal J, Martín-Pinto P. 2022. Prescribed burning in spring or autumn did not affect the soil fungal community in Mediterranean *Pinus nigra* natural forests. For Ecol Manag 512: 120161. DOI: 10.1016/j.foreco.2022.120161.

Wan JZ, Wang CJ, Yu FH. 2017. Wind effects on habitat distributions of wind-dispersed invasive plants across different biomes on a global scale: Assessment using six species. Ecol Inf 42: 38-45. DOI: 10.1016/j.ecoinf.2017.09.002.

Wan NF, Zheng XR, Fu LW, Kiær LP, Zhang Z, Chaplin-Kramer R, Dainese M, Tan J, Qiu SY, Hu YQ, Tian WD, Nie M, Ju RT, Deng JY, Jiang JX, Cai YM, Li B. 2020. Global synthesis of effects of plant species diversity on trophic groups and interactions. Nat Plants 6 (5): 503-510. DOI: 0.1038/s41477-020-0654-y.

Wang X, Li S, Huang S, Cui Y, Fu H, Li T, Zhao W, Yang X. 2021. *Pinus massoniana* population dynamics: Driving species diversity during the pioneer stage of ecological restoration. Glob Ecol Conserv 27: e01593. DOI: 10.1016/j.gecco.2021.e01593.

Widodo, Sutarno, Widoretno S, Sugiyarto. 2010. Taxonomic diversity of macroflora vegetation among main stands of the forest of Wanagama I, Gunung Kidul. Biodiversitas 11: 89-92. DOI: 10.13057/biodiv/d110207.

Wijaya IMS, Defiani MR. 2021. Diversity and distribution of figs (Ficus: Moraceae) in Gianyar district, Bali, Indonesia. Biodiversitas 22 (1): 233-246. DOI: 10.13057/biodiv/d220129.

Wijayanto A, Wardhana TW, Nurmadina, Darwitono. 2019. Produktivitas dan perbandingan produksi resin *Pinus merkusii* Jungh Et De Vriese terhadap Net Progress Schedule (NPS) yang ditetapkan Perhutani. Silva Tropika 3 (2): 199-205. [Indonesian]

Yang A, Zhang W, Qi F, He M. 2021. Research progress of national park community management based on Web of Science. Proceedings of the 7th International Conference on Social Science and Higher Education 598: 372-379. DOI: 10.2991/assehr.k.211122.119.

Yilmaz H, Yilmaz OY, Akyüz YF. 2017. Determining the factors affecting the distribution of *Muscari latifolium*, an endemic plant of Turkey, and a mapping species distribution model. Ecol Evol 7: 1112-1124. DOI: 10.1002/ece3.2766.