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Full Length Research Article

Current Distribution of a Luxurious Wood Species, *Diospyros* spp. with Its Climatic Information, based on Global Biodiversity Website

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ABSTRACT

Ebony (*Diospyros* spp.) is a fancy wood distributed in eastern Indonesia. *D. celebica* Bakh, *D. lolin* Bakh, *D. pilosanthera* Blanco, *D. ebenum* Koenig, *D. ferrea* (Wild.) Bakh and *D. rumphii* Bakh are categorized as "Fancy Wood Class I" in the Indonesian market. These woods are an important product with the highest tax compared to other grades. This study aimed to identify the distribution of six ebonies based on data global biodiversity web service (Global Biodiversity Information Facility) and their climatic condition based on global climate data (WorldClim). Data from the web service, species occurrence, and climatic conditions were processed using QGIS. Species occurrence data was then extracted using GBIF occurrence. Furthermore, species occurrence data was then overlaid with climate data using point sampling tools. The results found that three ebonies scattered in the tropics and three others (*D. celebica* Bakh, *D. rumphii* Bakh, *D. lolin* Bakh) mostly occurred in Indonesia. Annual rainfall and temperature conditions ranged from 1,722 – 4,013 mm and 23.4 – 27.2°C for the three species of ebony in Indonesia. The distribution and climatic conditions of ebony are the initial information for further research, such as the species distribution model related to climate change and the genetic conservation agenda.

1. Introduction

Ebony (*Diospyros* spp.) is a wood species of the Ebenaceae family, a luxury wood species in Indonesia (Djarwanto et al. 2017). Indonesia has 100 species of wood from the Diospyros genus (Kinho 2013), and only six species are classified as *Kayu Indah I* (Fancy Wood Class I) (Kinho 2014). These species are *Diospyros celebica* Bakh, *D. lolin* Bakh, *D. pilosanthera* Blanco, *D. ebenum* Koenig, *D. ferrea* (Wild.) Bakh and *D. rumphii* Bakh. Ebony usually has beautiful characteristics in color and contrast patterns that seem attractive (Asdar et al. 2015). The brown stripes on the heartwood determine the export destination of the ebony. Japanese mostly prefers brown stripes with a width of < 3 mm, but European and American markets prefer brown stripes > 3 mm wide (Kinho 2015).

In general, the habitat of ebony is lowland forest. Kinho (2014) explained that ebony could grow at an altitude of 0-400 m above sea level (masl). However, the diversity of ebony is reported to be lower at altitudes above 500 masl in the Tangkoko Nature Reserve, North Sulawesi (Kinho

2013). Lamada et al. (2016) also explained that a location with a rainfall of 1,200-2,750 mm/year could be a suitable habitat for ebony. In addition, ebony can also grow in moist climates with rainfall of 2,737 mm/year and in monsoon forests with rainfall of 1,709 mm/year (Kinho 2013).

Ebony wood has been a trading wood since the Dutch colonial era. Therefore, this wood species provides an enormous market demand opportunity. Japan, Korea, and Taiwan were the export destinations for ebony logs from 1969 to 1984 (Allo 2020). The principle of "no overcutting" on ebony species should be considered for sustainable forest management. The six species of ebony belonging to the Fancy Wood Class I have a special attractiveness, especially in terms of price. These wood species have maintained their status in the Fancy Wood Class I category since implementing the Decree of the Minister of Forestry No. 163/Kpts-II/2003. A recent report showed that these wood species still belong to the Fancy Wood Class I (Djarwanto et al. 2017).

The decreasing amount of ebony in natural forests occurs from time to time. Ebony has been harvested since the 17th century and continues today (Mokodompit et al. 2018). Prasetyawati and Kurniawan (2013) indicated that ebony in Sulawesi significantly decreased due to uncontrolled exploitation. Likewise, Kurniawan (2013) also mentioned that timber harvesting, shifting cultivation, and the inadequacy of successful replanting contributed to the decline in the ebony population. Ex-situ ebony conservation has been widely performed (Allo 2020; Wanda et al. 2019). An example is the ex-situ planting of *D. celebica* in the Wanagama Education Forest, Faculty of Forestry, Universitas Gadjah Mada. This wood species was planted under shade plants and shows a 100% survival rate and grows as expected (Ernawati 2016).

There is no comprehensive information on the distribution of ebony concerning the climate suitability aspect. Detection of the distribution and population of indigenous species is important, usually by the direct ground survey method, utilizing secondary (terrestrial) spatial data, or a combination of both methods (Shitara et al. 2021). The data on the distribution of wood species commonly used is the Global Biodiversity Information Facility (GBIF) data. GBIF provides the data for free and open access online. GBIF provides data on the geographical and temporal presence of certain species of organisms and data on observed species (Wieczorek et al. 2012). In addition, global climate data can be observed by Web WordClim data; it usually provides high resolution (up to 1 km^2) containing data on rainfall, temperature, water vapor pressure, wind speed, and solar radiation (Hijmans et al. 2005). The latest version of WorldClim data used more than 60,000 and 47,000 weather stations for rainfall and temperature parameters (Fick and Hijmans 2017). The two global data have the same strengths: they are easily accessible and can be updated by the public. Studies that utilized GBIF data have been shown to increase. In 2008, 58 articles used GBIF data, and in 2019, there were 743 articles (GBIF 2021). In particular, such articles by Indonesian researchers have been increased from 1, 4, to 5 from 2016, 2017 to 2018, respectively (GBIF 2020). In 2019 peer-reviewed articles from Indonesian researchers were categorized as a medium, with about 10-19 articles (GBIF 2021). The number of peer-reviewed studies using WordClim 1.4 data (early version) for species distribution model (SDM) research was recorded at 2,660 articles. This number was recorded until 2019, in which year WordClim 2.1 (new version) had not been released (Cerasoli et al. 2022).

By utilizing GBIF and WorldClim data, this study aimed to determine the presence and distribution of 6 species of ebony in Indonesia and investigate the temperature and annual rainfall where they grow. This information has implications for knowledge of the climatic characteristics

of ebony species. In addition, this study can also provide primary data for modeling study to predict suitable locations for ebony plantations for both conservation and commercial purposes.

2. Materials and Methods

2.1. Data Source

This study reviewed the data on the presence of various species of ebony from web services and estimated the climatic conditions at the location of the presence. The two data sources used were based on free-access websites (**Table 1**).

Table 1. Two sources of research data

Source	Service Availability	Extracted data	URL
GBIF	Dataset species	Latitude, longitude	https://www.gbif.org
WordClim	High-resolution bioclimatic data	Annual rainfall Annual temperature	https://www. WorldClim.org _

2.2. Data Collection

GBIF occurrence tools in QGIS (QGIS Development Team 2019) were used to obtain the presence data for the six species of ebony (GBIFa-f 2021). Furthermore, this coordinate data was used to extract WorldClim data for each species. Then, if geographic coordinates were found without any climatic data, the data will not be used for further analysis (unselected data). On the other hand, the selected data in the form of coordinates with rainfall and temperature data were further processed and compared with annual rainfall and temperature throughout Indonesia. Technically, GBIF occurrence was more practical than the manual step of downloading GBIF data and uploading it to QGIS. GBIF Occurrence tools directly downloaded and imported species presence data in QGIS. The steps for using this tool were installing, entering "scientific names", and then loading. This study showed that with this tool, the distribution of the six species of *Diospyros* spp. can be directly seen in QGIS, which was connected to the internet network for the download process.

Point sampling tools in QGIS (QGIS Development Team 2019) were used to obtain annual rainfall and temperature data from 1970 to 2000 obtained from WorldClim 2.1 with a resolution of 2.5 minutes (5 km at the equator). This resolution was the highest resolution compared to other resolutions in WorldClim 2.1, namely 5 and 10 minutes or about 10 and 20 km at the equator (Cerasoli et al. 2022). Point sampling tools in QGIS were used because of the ease of extracting annual rainfall and temperature data based on predetermined points. This tool was used to retrieve/extract data from raster cells (e.g., TIFF file for WordClim data) or data from polygons. The use of this tool comprised of two stages: the extraction of climate data on the coordinates of the presence of species and the extraction of climate data for all regions in Indonesia.

2.3. Result Visualization

The visualization of the results was performed in two ways, namely data on the distribution of *Diospyros* spp. in Indonesia and the results of overlaying climate data of those species. The species distribution map is displayed via QGIS (QGIS Development Team 2019). Climatic data

throughout Indonesia and ebony climate data were plotted using R software version 4.03 (R Core Team 2020) with annual temperature as the x-axis and annual rainfall as the y-axis. The flow chart of this research is presented in **Fig. 1**.

2.4. Result Analysis

The analysis was conducted descriptively by comparing the climatic conditions between the present study results and previous studies. The distribution of species from previous studies became references for discussing the data.

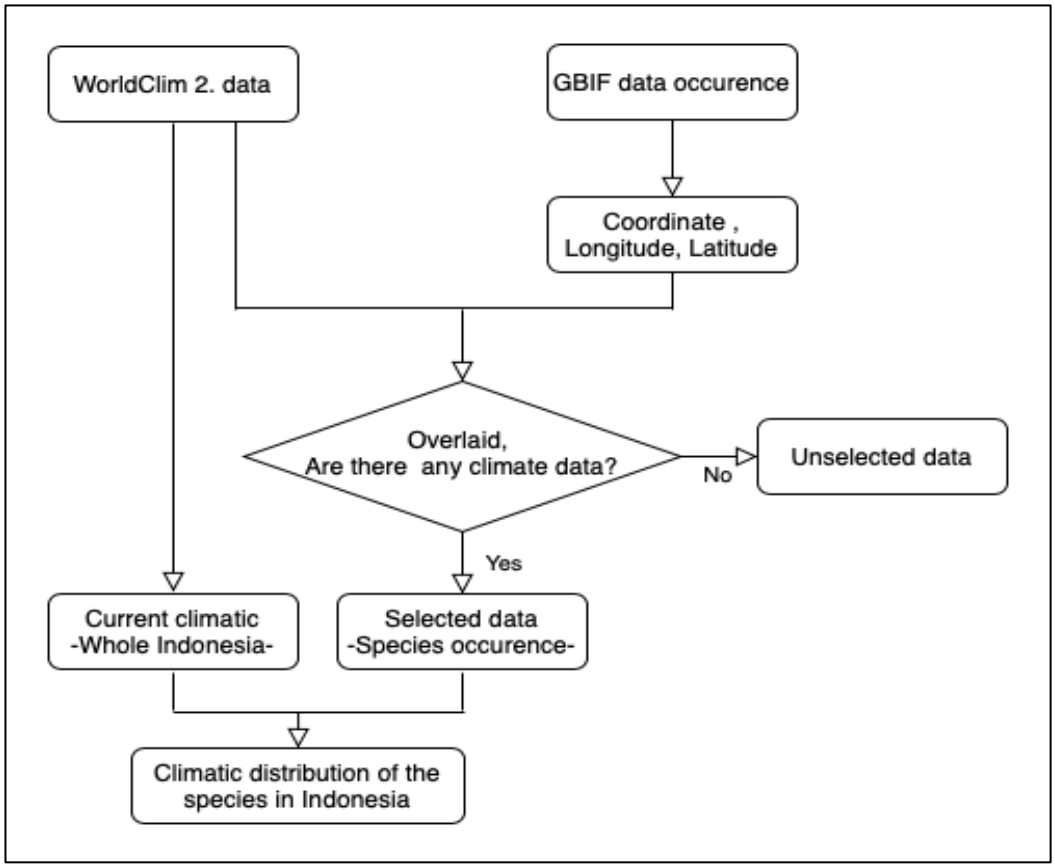

Fig. 1. Research flow chart.

3. Results and Discussion

3.1. Ebony Distribution

Ebony is famous as a fancy wood from eastern Indonesia. Specific locations based on presence data were identified in this study. The distribution of the six ebony species varies greatly in terms of number and distribution. The distribution was categorized into two types: those found in Indonesia (**Fig. 2**) and those recorded in the tropical regions of the world (**Table 2**). The widest distribution recorded is *D. ferrea,* and the smallest is *D. rumphii*.

Table 2. Total presence and distribution of ebony species according to the GBIF biodiversity web service

No	Species	Presence	Distribution
1.	*D. celebica*	26	3 Countries: Indonesia, Malaysia, Papua New Guinea
2.	*D. rumphii*	6	Indonesia
3.	*D. lolin*	32	2 Countries: Indonesia, Papua New Guinea
4.	*D. ebenum*	18	9 Countries: Brazil, Cameroon, Honduras, India, Indonesia, Mongolia, Papua New Guinea, Sri Lanka, USA
5.	*D. pilosanthera*	289	9 Countries: Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Papua New Guinea, Philippines, Singapore, Thailand
6.	*D. ferrea*	772	43 Countries: Angola, Australia, Benin, Burkina Faso, Cambodia, Cameroon, Central African Republic, China, Chinese Taipei, Congo, Ivory Coast, Fiji, Gabon, Guinea, Guinea-Bissau, India, Indonesia, Japan, Laos, Liberia, Madagascar, Malaysia, Mali, Mongolia, Mozambique, Myanmar, New Caledonia, Nigeria, Palau, Papua New Guinea, Philippines, Senegal, Sierra Leone, Solomon, Sri Lanka, Tanzania, Thailand, Togo, USA, Vanuatu, Vietnam

The presence of the species on the GBIF web service did not fully reflect the field conditions. This tendency depended on the reporting/disability data submitted to the GBIF. *D. rumphii* has the smallest distribution because the number of data recorded is only 6 data from 2 locations. This species is also categorized as DD (Data Deficient) in the IUCN Red List (IUCN 2021). *D. rumphii* was reported to have a wider distribution than *D. celebica* (Alrasyid 2002).

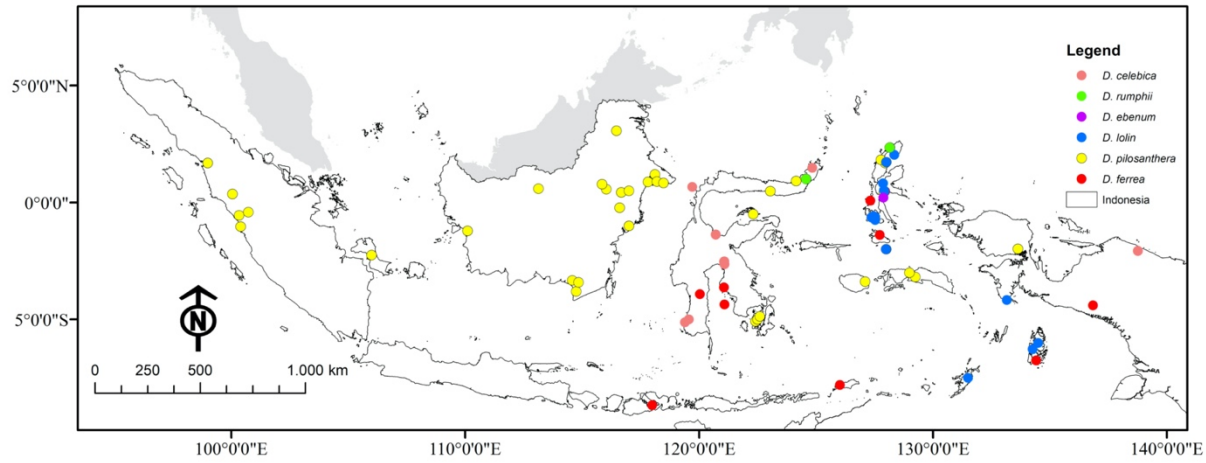

Fig. 2. The distribution of ebony in Indonesia based on the presence of species on the GBIF web service.

This study revealed several things that are in line with previous research. First, this study confirmed that the only ebony species in Indonesia are *D. rumphii* and *D. celebica* (Alrasyid 2002; Darmawan et al. 2021). Second, *D. ferrea* has the widest distribution compared to the other five species of ebony (**Table 2**) (Alrasyid 2002; Rindyastuti et al. 2021). These two things can be the basis for consideration in developing this Fancy Wood Class I species in the future.

D. celebica was recorded in 26 presence data in 3 countries. Particularly in Indonesia, this species was recorded in Sulawesi and Papua. Rindyastuti et al. (2021) reported that this species is naturally distributed in Sulawesi. Likewise, Karlinasari et al. (2020) also reported that *D. celebica* had been identified as having different extractive substances at growth sites in West Sulawesi, Central Sulawesi, and South Sulawesi Province. Therefore, the development of this species in Papua can be considered for future management. However, site validation and crosschecks are essential for such cases.

D. rumphii was found in six presence data in two locations, namely north of Sulawesi Island and north of Halmahera Island. This study was in line with Alrasyid (2002), that mentioned the exact location for the natural distribution of *D. rumphii*. Kinho et al. (2016) explained that the lack of presence data of *D. rumphii* was implicated in protecting this wood species, especially the preservation of its genetic resources. The IUCN red list stated that *D. rumphii* is classified as DD or *Data Deficient* (IUCN 2021). The DD category indicates the species was difficult to find in the field, so it is directly proportional to the distribution of the population.

Apart from Papua New Guinea, *D. lolin* was recorded on the islands of Halmahera and Papua. These results are supported by the data collection from the Bogor Botanical Garden, which has four species from Halmahera and Papua (Wanda et al. 2019). In contrast*, D. ebenum,* a native species to India and Sri Lanka (Jeyavanan et al. 20 16), was recorded in 1 presence data in Halmahera Island, Indonesia. The lack of presence of this species might be due to inadequate published data about this species in Indonesia which was reported on the GBIF Web. This tendency was also supported by the report of Alrasyid (2002) that *D. ebenum* naturally spreads in Minahasa, Poso, Buton, Tanibar, Aru, Sumbawa and Flores. Meanwhile, *D. pilosanthera* was found scattered on the major Indonesian islands other than Java (**Fig. 2**). However, this species requires attention in safeguarding genetic diversity (Kinho 2015).

3.2. Annual Precipitation and Temperature in Ebony Habitat based on WorldClim 2.1

Climatic data showed that, in general, the presence of the six species of ebony is in the range of temperature and annual rainfall in Indonesia (**Fig. 2**; **Table 3**). However, a small part of *D. ebenum*, *D. pilosanthera,* and *D. ferrea* were outside Indonesia's temperature and rainfall range (**Fig. 2d-f**). These results proved that the three species have a wider climatic range and have the potential to be developed in other countries.

This study added climatic information for each species of ebony. This information is useful for developing ebony plantations for ex-situ conservation and timber production. For example, the ex-situ conservation of *D. celebica*, which began in 1940, has been successful and has already reached the domestication stage (Alrasyid 2002). Therefore, it can be suggested to be applied to other ebony species in locations with climatic specifications close to this study's findings (**Table 3**).

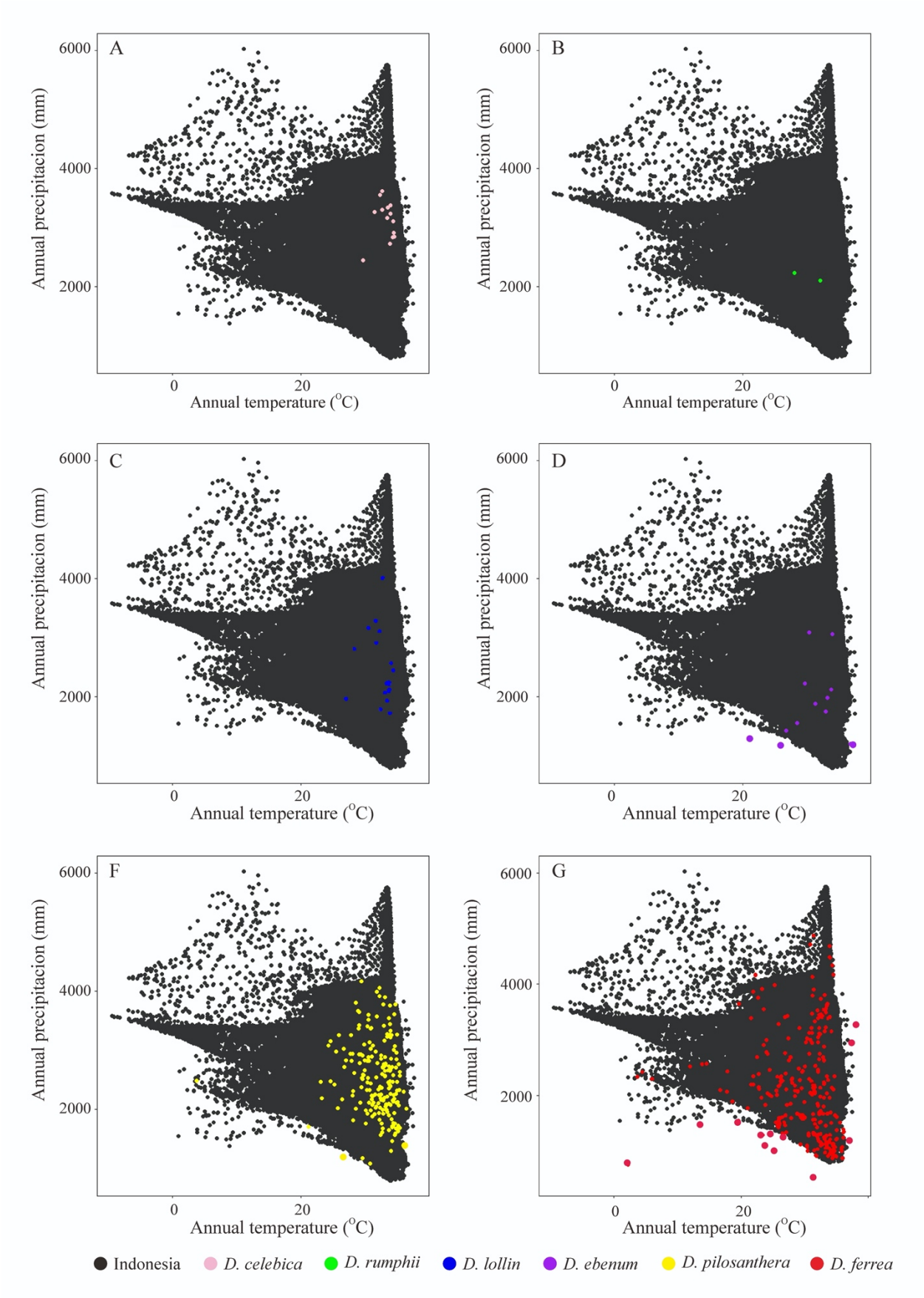

Fig. 2 . Climatic conditions of ebony species with conditions in Indonesia.

Table 3. Climatic data of the six ebonies studied

No	Species	WorldClim data**		Literature Data	
		Rainfall (mm/year)	Temperature (°C)	Rainfall (mm/year)	Temperature (°C)
1.	*D. celebica*	2,448 - 3,618	24.8 - 27.2	1,709 - 2,737 according to Alrasyid (2002)*	21.5 - 30 according to Alrasyid (2002)*
2.	*D. rumphii*	2,099 - 2,311	24 - 26		
3.	*D. lolin*	1,722 - 4,013	23.4 - 27.1		
4.	*D. ebenum*	1,168 – 3,091	22.9 - 28.5		
5.	*D. pilosanthera*	1,084 – 4,171	21.6 - 28.1		
6.	*D. ferrea*	474 – 4,873	21.4 - 28.1		

Notes: * This literature summarizes climate data on 7 ebony species (6 species in the table and *D. macrophylla* species). ** Data from 1970 - 2000 was obtained from WorldClim 2.1 with a resolution of 2.5 minutes (5 km at the equator).

Climatic data per species of ebony can be used for SDM study as the current environmental data for analyzing the impact of climate change. Information on annual rainfall (bio 12) and annual temperature (bio 1) on the six species of ebony is some of the bioclimatic information (bio 1 – bio 19) which is commonly used for SDM studies. Further studies on the impact of climate change on ebony are needed to be investigated as has been reported on several tropical plants before, such as *Melaleuca cajuputi* (Ab Lah et al. 2021), *Baccaurea angulate* (Gunawan et al. 2021), and *Styrax sumatrana* (Saputra and Lee 2021).

The results of this study have a considerable impact on the genetic conservation efforts of ebony. The results showed that the population of this species was indicated to be very narrow by the small number of presences. However, a field-scale survey is recommended to confirm these findings. Genetic conservation of ebony has been investigated in several species, including *D. celebica* (Suhartati and Alfaizin 2020) and *D. rumphii* (Kinho 2014). Furthermore, information on climate suitability for ebony distribution provides an opportunity to predict the adaptability of this species to climate change. Projections of distribution and population size of ebony in the future need to be identified further by considering aspects of climate change to plan genetic conservation actions in order to avoid the extinction of ebony species.

4. Conclusions

The distribution of ebony is categorized into three species in the tropics of the world and three species (*D. celebica* Bakh, *D. lolin Bakh*, *D. rumphii* Bakh) dominant in Indonesia. Annual rainfall and temperature conditions ranged between 1,722 – 4,013 mm and 23.4 – 27.2°C for species of ebony in Indonesia. The distribution and climatic conditions of ebony are the initial information for further research, such as the site suitability study with the species distribution model.

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