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Endemic Bamboo (Poaceae, Bambusoideae) of the Lesser Sunda Islands

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Abstract. *More than 40 species of bamboo were known from the Lesser Sunda Islands (LSI), including several endemic species. Endemic species are often highly specialized, found in limited geographical areas, and vulnerable to extinction if their habitat is destroyed. This study aimed to provide an account of endemic bamboo species on the LSI. Fieldwork involved collecting samples of bamboo in the LSI. Herbarium specimens of bamboo deposited in the Herbarium Bogoriense (BO), collected from the LSI were examined, and endemic LSI species were recorded. The conservation status followed the International Union for Conservation of Nature (IUCN) red list categories and criteria. The conservation status of unassessed species was evaluated using IUCN red list categories and criteria. A spatial analysis was also conducted. Data were analyzed and presented descriptively. There are 10 endemic bamboo species in the LSI, namely Bambusa ooh Widjaja & Astuti from Bali (conservation status: endangered), Chloothamnus reholttumianus (Soenarko) Widjaja from Sumba (vulnerable), C. schmutzii (S.Dransf.) Widjaja from Sumbawa and Flores (near threatened), Dinochloa kostermansiana S.Dransf. from Sumba and Flores (near threatened), D. sepang Widjaja & Astuti from Bali (vulnerable), Fimbribambusa rifaiana Widjaja from Alor (near threatened), Gigantochloa aya Widjaja & Astuti from Bali (vulnerable), G. baliana Widjaja & Astuti from Bali (vulnerable), G. taluh Widjaja & Astuti from Bali (vulnerable), and Schizostachyum purpureum Damayanto & Widjaja from Sumba (data deficient). They can be found at an altitude of 20–1700 m in various habitats, including forests, bamboo forests, villages, botanical gardens, along a road, slopes, valleys, riverbanks, and around a lake.*

Keywords: *Bambusoideae, conservation, distribution, endemic, IUCN, taxonomy*

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INTRODUCTION

The Lesser Sunda Islands (LSI), also known in Indonesian as *Kepulauan Sunda* Kecil, is a group of islands with an area of 73,070.48 km² (Retnowati & Rugayah, 2019) located in Southeast Asia and consisting of (from the west to the east) Bali, Lombok, Sumbawa, Sumba, Flores, Timor, Alor, Wetar, and Tanimbar Islands (Steenis-Kruseman, 1950). Geographically, the LSI situated between Java Islands in the west, Australia in the south, Papua New Guinea in the east, and the Banda Sea and Sulawesi in the north, stretched

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from 8°11’57.6” S and 114°25’14.3” E in the west to 7°26’28.7” S and 132°19’22.6” E in the east. Administratively, the LSI are part of Indonesia (Province of Bali, West Nusa Tenggara, East Nusa Tenggara, and Maluku) and East Timor (half of Timor Island).

In 2017, a total of 3,243 species of flora and fungi were reported found in the LSI (Retnowati & Rugayah, 2019). The LSI is home to 208 species of grasses (Poaceae) family (Retnowati & Rugayah, 2019). Of this Poaceae, 45 species of bamboo (Bambusoideae) were found in the LSI (38 species in Bali and 19 species in Nusa Tenggara) (Widjaja, 2019). There are 1,343 endemic plant species in the LSI reported (Widjaja et al., 2014), including 12 species of bamboo (Widjaja, 2019). Endemic species are found in limited geographical areas, are often highly specialized, and can be endangered if their habitat is destroyed. Endemic species are particularly important to protect because they often have unique genetic, ecological, and evolutionary characteristics.

Endemic species face various threats, such as habitat loss (Myers et al., 2000), degradation, and fragmentation (Işik, 2011), as well as climate change (Manes et al., 2021; Mahmoodi et al., 2022). On the other hand, human activities such as land use (Işik, 2011; Ghorbanalizadeh & Akhani, 2022), introduction of invasive species (Foggi et al., 2015; Pinto-Junior et al., 2020), and overexploitation of natural resources can pose significant threats to endemic species, increasing the risk of extinction (Işik, 2011). Therefore, the conservation of endemic bamboo is crucial to maintain the biodiversity and ecological balance of their habitats. Since there is a lack of information on endemic bamboo in the LSI, there is an urgent need to provide information on the distribution and conservation status of these species. This study aimed to identify areas of high conservation priority for the protection of endemic bamboo and provide a basis for conservation efforts. The findings of this study will contribute to our understanding of the diversity, distribution, and conservation of endemic bamboo species in the LSI.

MATERIALS AND METHODS

This study is exploratory research conducted in LSI, including Bali (in 2021), Lombok (in 2018 and 2019), Sumbawa (in 2019), Sumba (in 2016), and Timor (in 2021) (Figure 1). Fieldwork involved collecting bamboo samples, including young shoots, branches, leafy branches, culm sheaths, and flowers (if available), using the Rugayah et al. (2004) method. Each sample was labeled with the collector's name, collection number, and date, and non-collectible morphological characteristics (culm height, diameter, internode length, surface texture, and color of culms and leaves) were recorded. Location, coordinates, altitude, local names, uses, and habitats were also documented. Samples were sent to the Herbarium Bogoriense (BO) and processed as herbarium specimens following the method described by Djarwaningsih et al. (2002). All herbarium specimens were stored at the BO. Specimens were identified by comparing with specimens stored in the BO and using protologues or literature such as Soenarko (1977), Widjaja (1987, 1997, 2001, 2020), Dransfield (1980, 1996), Widjaja et al. (2004, 2005), and Damayanto & Widjaja (2016).

Specimens of bamboo deposited in the BO, collected from the LSI, were examined, and endemic LSI species were recorded. High-resolution images of specimens collected from the LSI were also examined on several online database portals (Damayanto & Irsyam, 2022). Accepted names of bamboo were validated according to Vorontsova

et al. (2016), Widjaja & Wong (2016), and online database portals (Damayanto et al., 2020b). Literature such as Soenarko (1977), Dransfield (1980, 1996), Dransfield & Widjaja (1995), Agung & Hardini (1997), Widjaja (1997, 2001, 2019, 2020), Widjaja et al. (2004, 2005, 2014), Arinasa (2005), Arinasa & Widjaja (2005), Widjaja & Karsono (2005), Arinasa & Peneng (2013), Arinasa & Sujarwo (2015), Damayanto (2016, 2017), Damayanto & Widjaja (2016), Vorontsova et al. (2016), Widjaja & Wong (2016), Damayanto et al. (2018, 2020a, 2020c), Muzakki (2020), and Kurniawan et al. (2022), was consulted for additional data. The conservation status followed the International Union for Conservation of Nature red list categories and criteria (https://www.iucnredlist.org). The conservation status of unassessed species was evaluated using IUCN (2022). The criteria consider geographic range (area of occupancy or AOO and extent of occurrence or EOO) and habitat quality to determine a species' conservation status. AOO (based on a cell width of 2 km) and EOO were calculated using an online application (https://geocat.kew.org). We also conducted a spatial analysis using the online application (http://simplemappr.net). Bamboo distribution maps across land covers of the LSI were plotted using QGIS v. 3.10 software with a database in 2019 from https://www.indonesia-geospasial.com. Data were analyzed and presented descriptively, and an identification key to the endemic bamboo species to the LSI was also presented.

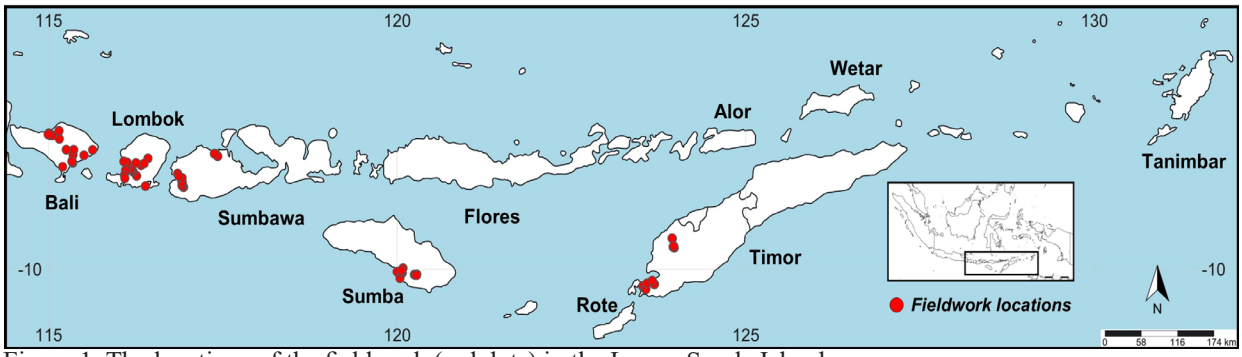

Figure 1. The locations of the fieldwork (red dots) in the Lesser Sunda Islands

RESULTS AND DISCUSSION

There are 10 species of endemic bamboo in the LSI, namely *Bambusa ooh* Widjaja & Astuti, *Chloothamnus reholttumianus* (Soenarko) Widjaja, *C. schmutzii* (S.Dransf.) Widjaja, *Dinochloa kostermansiana* S.Dransf., *D. sepang* Widjaja & Astuti, *Fimbribambusa rifaiana* Widjaja, *Gigantochloa aya* Widjaja & Astuti, *G. baliana* Widjaja & Astuti, *G. taluh* Widjaja & Astuti, and *Schizostachyum purpureum* Damayanto & Widjaja (Table 1 and Figure 2). Widjaja (2019) stated that there were 12 species of endemic bamboo in the LSI (she separated Bali from the LSI, but in this study was combined) (Table 2). Widjaja (2019) listed *B. ooh* as an endemic species to Java instead of Bali, although, this species was endemic to Bali (Widjaja et al., 2004, 2005; Arinasa & Peneng, 2013; Arinasa & Sujarwo, 2015; Vorontsova et al., 2016). Additionally, *G. baliana* was listed as an endemic species to Sumatra (Widjaja, 2019), but it was only found in Bali (Widjaja et al., 2004, 2005; Arinasa & Peneng, 2013; Arinasa & Sujarwo, 2015; Vorontsova et al., 2016) and there was no *G. baliana* specimen from Sumatra. Conversely, *S. purpureum*, endem-

ic to Sumba (Damayanto & Widjaja, 2016; Damayanto et al., 2018), was not listed as an endemic species by Widjaja (2019). Furthermore, Muzakki (2020) found *S. castaneum* in Java, meaning it is no longer considered an endemic species to Bali. This study did not include *Gigantochloa* sp.2, *Gigantochloa* sp.3, and *Gigantochloa* sp.4 which Widjaja (2019) reported as being endemic to Bali because their taxa status needed to be clarified. Ensuring that species distributions are accurately reported and that the taxonomic status of species provided is crucial for supporting effective conservation efforts.

Table 2. Comparison list of endemic bamboo species in the Lesser Sunda Islands in 2019 and 2023

Widjaja (2019)	**Recent Study (2023)**	**Notes**
-	*B. ooh*	Widjaja (2019) listed *B. ooh* as an endemic species to Java, instead of Bali. In fact, this species is endemic to Bali (Widjaja et al., 2004, 2005) especially in Karangasem and there are no specimens of *B. ooh* in Java.
C. reholttumianus	*C. reholttumianus*	Endemic to Sumba (Mangiliwari near Maumarru).
C. schmutzii	*C. schmutzii*	Endemic to the LSI (Batulanteh, Werak, and Manggarai).
D. kostermansiana	*D. kostermansiana*	Endemic to the LSI (Manggarai, Laiwangi-Wanggameti, and Manupeu-Tanahdaru).
D. sepang	*D. sepang*	Endemic to Bali (Bangli, Buleleng, Gianyar, Jembrana, and Karangasem).
Fimbribambusa sp.2 (Alor)	*F. rifaiana*	Widjaja (2019) mentioned that *Fimbribambusa* sp.2 (Alor) is endemic to Alor. We supposed that *Fimbribambusa* sp.2 (Alor) has been published on Widjaja (2020) as *F. rifaiana*, an endemic species to Kalabahi, Alor.
G. aya	*G. aya*	Endemic to Bali (Bangli).
G. baliana	*G. baliana*	Besides Bali, Widjaja (2019) also mentioned that *G. baliana* occurred in Sumatra and listed it as an endemic species. In fact, this species was found in Bali only (Widjaja et al., 2004, 2005), especially in Buleleng and there is no *G. baliana* specimen from Sumatra.
G. taluh	*G. taluh*	Endemic to Bali (Bangli).
Gigantochloa sp.2 (*jajang abu*) (Bali)	-	Status of this species is unclear, so it is not included in this paper.
Gigantochloa sp.3 (*tiying mambang*) (Bali)	-	Status of this species is unclear, so it is not included in this paper.
Gigantochloa sp.4 (*tiying pusut*) (Bali)	-	Status of this species is unclear, so it is not included in this paper.
S. castaneum	-	Muzakki (2020) found *S. castaneum* in Java recently, therefore, this species is no more endemic to Bali.
-	*S. purpureum*	Widjaja (2019) not listed this species as an endemic species, whereas, this species is endemic to Laiwangi-Wanggameti National Park, Sumba (Damayanto & Widjaja, 2016).
12 species	**10 species**	

Jurnal Biodjati 8(1):1–12, May 2023

JURNAL BIODJATI

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Table 1. Detailed account of the endemic bamboo species in the Lesser Sunda Islands, include their respective local names, growth habits, geographical distribution, extent of occurrence, area of occupancy, presence in protected areas and botanical gardens, IUCN status, and potential uses

Species	Local Names	Habits	Distribution							EOO (km^2)	AOO (km^2)	Occurs in Protected Area	Ex-situ Conservation in BG	IUCN Status	Uses
			Bi	Lk	Sb	Sa	Fr	Tr	Ar						
B. ooh	*Tiying ooh*	E	+×							0	4	No	Yes	EN	Building materials, webbing (*gedek*)
C. reholttumianus	*Oru*	S				+				0	4	No	No	VU	-
C. schmutzii	*Heso, ropeng*	S			+		+			3637	20	No	No	NT	-
D. kostermansiana	*Betung batu, lulu ura, oro bata, wesang*	C	×			+	+			6214	20	Yes: NP	Yes	NT	Building materials
D. sepang	*Tali-tali, tiing ludlud, tiing liplip, tiing alas, tiing-tiing, tiing sudamala, tiying sepang,*	C	+×							1277	36	No	Yes	VU	Walking stick
F. rifaiana	*Ia uting*	S							+	0	4	No	No	NT*	-
G. aya	*Jajang aya, tiying aya*	E	+×							0	4	No	Yes	VU	Building materials, webbing (*gedek*), charcoals, handicrafts (wind chimes)
G. baliana	*Betung bali, tiing petung bali, tiing bali*	E	+×							6.5	16	No	Yes	VU	Baskets, balinese baskets (*sokasi*), Balinese offering (*penjor*)
G. taluh	*Jajang taluh*	E	+×							0	4	No	Yes	VU*	Building materials, webbing (*gedek*), *sokasi*, handicrafts (wind chimes)
S. purpureum	*Au tamiyang*	E				+				0	4	Yes: NP	No	DD	Webbing (*gedek*), flute

C = climbing, E = erect, S = scrambling, Bi = Bali, Lk = Lombok, Sb = Sumbawa, Sa = Sumba, Fr = Flores, Tr = Timor, Ar = Alor, EOO = extent of occurrence, AOO = area of occupancy, km^2 = square kilometer, BG = Botanical Garden, NP = National Park, DD = Data Deficient, EN = Endangered, NT = Near Threatened, VU = Vulnerable, IUCN = International Union for Conservation of Nature, + = present, × = ex-situ conservation at "Eka Karya" Bali Botanical Garden, * = assessed by authors

Jurnal Biodjati 8(1):13–28, May 2023

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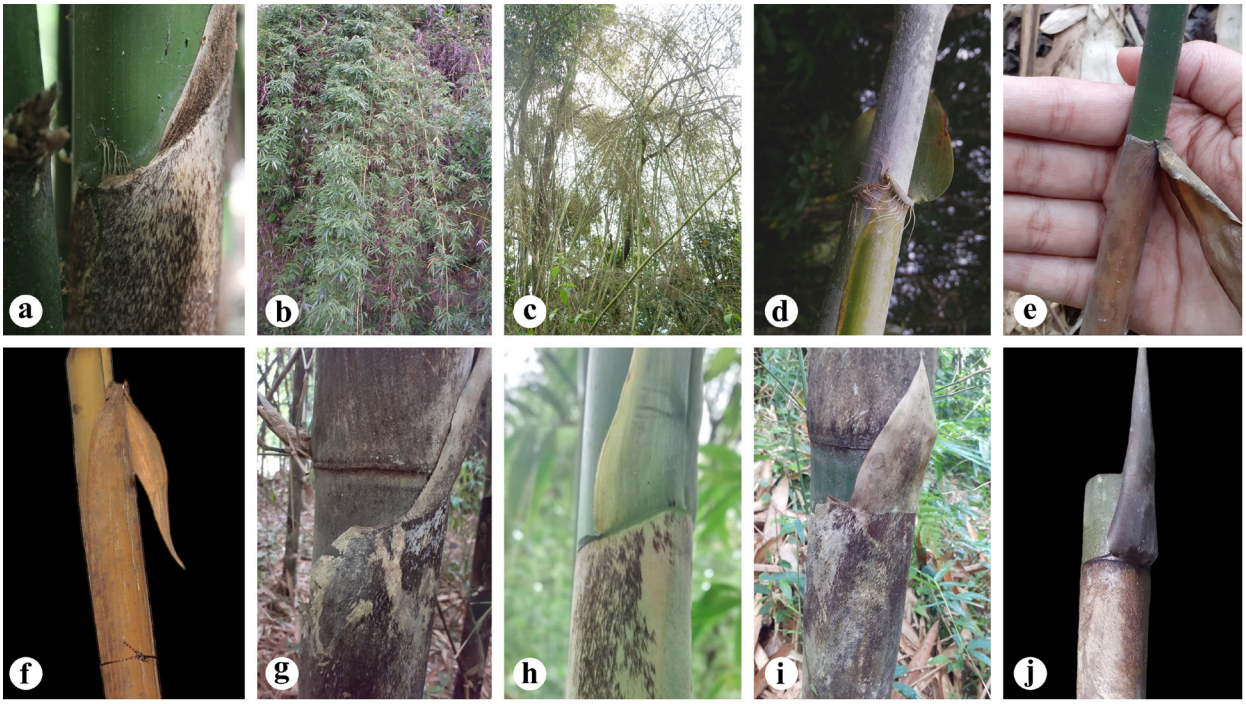

Figure 2. Endemic bamboo of the Lesser Sunda Islands: *Bambusa ooh* (a), *Chloothamnus reholttumianus* (b), *Chloothamnus schmutzii* (c), *Dinochloa kostermansiana* (d), *Dinochloa sepang* (e), *Fimbribambusa rifaiana* (f), *Gigantochloa aya* (g), *Gigantochloa baliana* (h), *Gigantochloa taluh* (i), and *Schizostachyum purpureum* (j). Photos: I. B. K. Arinasa (a), Widjaja et al. (2005) (b), L. D. Sulistyaningsih (c), I. P. G. P. Damayanto (d, f, g, i, j), N. K. D. Regiani (e), and G. M. Sudirga (h).

The endemic bamboo species found in the LSI are spread unevenly across all the islands in the region. The LSI's endemic bamboo species are restricted to certain islands (mostly in the main islands), including Bali, Sumbawa, Sumba, Flores, and Alor (Figure 3). The main islands of Lombok (see Damayanto et al., 2020c) and Timor have no endemic bamboo species. Most of the endemic bamboo species are specific to a single island, except for *C. schmutzii*, found on Sumbawa and Flores, and *D. kostermansiana*, found in Flores and Sumba. Bali Island has the largest number of endemic species (5 species and 1 species conserved from Sumba), followed by Sumba Island with 3 endemic species. Compared to other islands in the LSI, several researchers have extensively studied bamboo in Bali and Sumba (*see* Soenarko, 1977; Dransfield, 1996; Agung & Hardini, 1997; Widjaja et al., 2004; Arinasa, 2005; Widjaja & Karsono, 2005; Arinasa & Sujarwo, 2015; Damayanto, 2016; Damayanto & Widjaja, 2016; Damayanto et al., 2018). Therefore, a wealth of data is available on bamboo in this region. There is currently no available data about bamboo in the small or satellite islands of the LSI, such as in Nusa Penida, Moyo, Komodo, Rinca, Sawu, Rote, Lembata, Marisa, Wetar, and Babar. Exploring these areas is necessary to increase our understanding of the diversity of bamboo in the LSI. For instance, Widjaja (2020) recently discovered a new bamboo species, *F. rifaiana*, from Alor, a small island belonging to Flores. However, there is still a need for further exploration in the main islands of the LSI, particularly in remote areas where unknown bamboo species

or new distributions of existing species may be discovered. For example, *C. schmutzii* was found in Sumbawa based on exploration conducted in 2015 and 2016 (Damayanto et al., 2020a), which was previously only known to originate from Flores (Dransfield, 1980). *Dinochloa kostermansiana* was initially only known to originate from Flores (Dransfield, 1996); however, it was later also discovered in Sumba (Widjaja, 2001; Damayanto, 2016, 2017; Damayanto et al., 2018) based on explorations conducted by D. Sulistiarini and T. Uji in 1984 as well as E. A. Widjaja and Karsono in 2003 (Widjaja & Karsono, 2005)

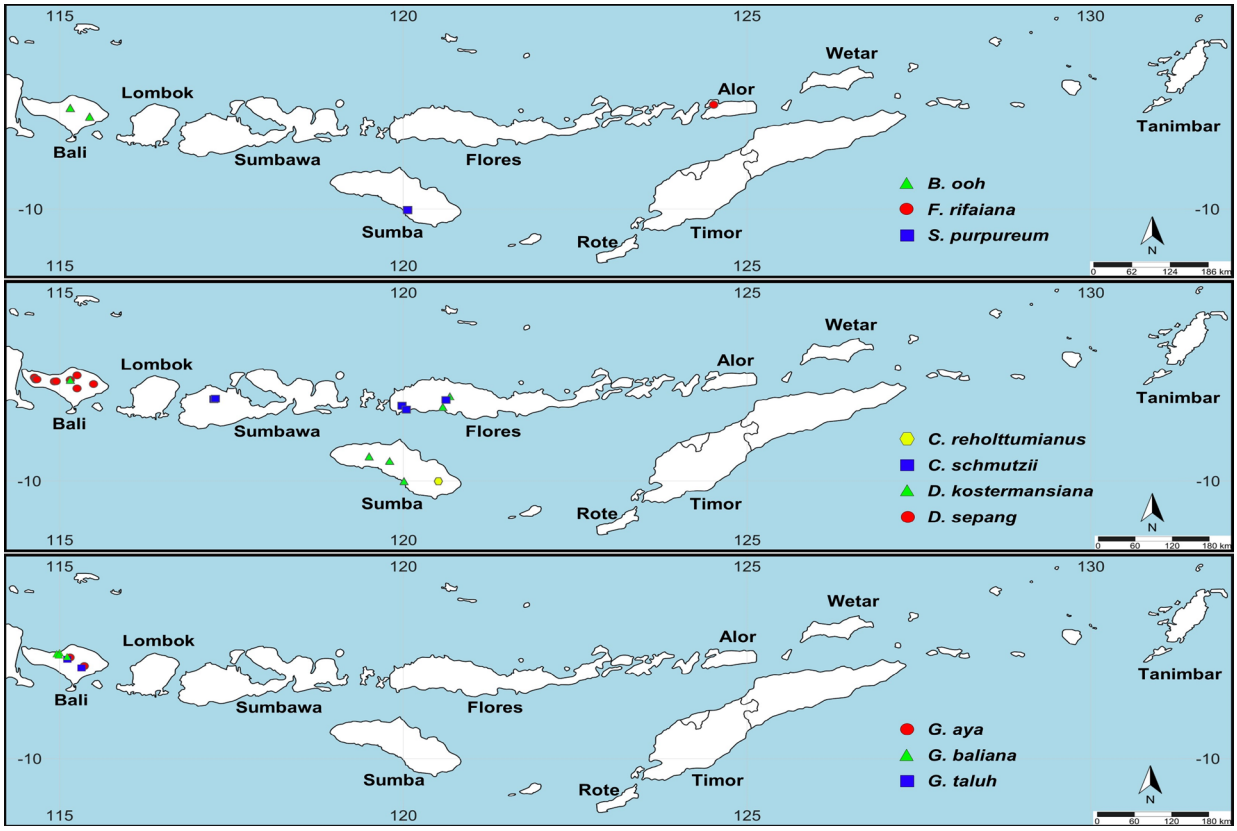

Figure 3. Distribution map of endemic bamboo in the Lesser Sunda Islands

The endemic bamboo species of the LSI grow within a wide range of altitudes, from 20 to 1700 m asl (Figure 4). *Bambusa ooh*, *D. kostermansiana*, *D. sepang*, *G. aya*, *G. baliana*, and *G. taluh* have a wide altitude range and have been cultivated in the "Eka Karya" Bali Botanical Garden, located at 1200–1450 m asl (Kurniawan et al., 2022). In their natural habitat, *B. ooh*, *D. kostermansiana*, *D. sepang*, and *G. taluh* can grow at altitudes ranging from 260 to 1700 m asl. Most of these species can grow above 1000 m asl, explaining their adaptability to the "Eka Karya" Bali Botanical Garden's altitude of approximately 1400 m. In contrast, *F. rifaiana* only grows at an altitude of 20 m, while *S. purpureum* only grows at 525 m (Figure 4). Limited data on their natural habitats (see Damayanto & Widjaja, 2016; Widjaja, 2020) suggests that both species can only be found at altitudes of 20 and 525 m asl. However, if their populations are surveyed or explored, both species may be found growing at higher or lower altitudes, as bamboo growth appears to be less influenced

by altitude. For example, *C. schmutzii* was previously known to grow at altitudes of 600–850 m in Flores but has recently been found growing up to 1083 m asl in Sumbawa (Damayanto et al., 2020a). Additionally, although *G. aya* is naturally found at altitudes ranging from 400 to 700 m (Arinasa & Peneng, 2013; Arinasa & Sujarwo, 2015) and *G. baliana* at an altitude of 600–800 m (Arinasa & Peneng, 2013), both species have shown adaptability to an altitude of 1400 m after being planted in the “Eka Karya" Bali Botanical Garden.

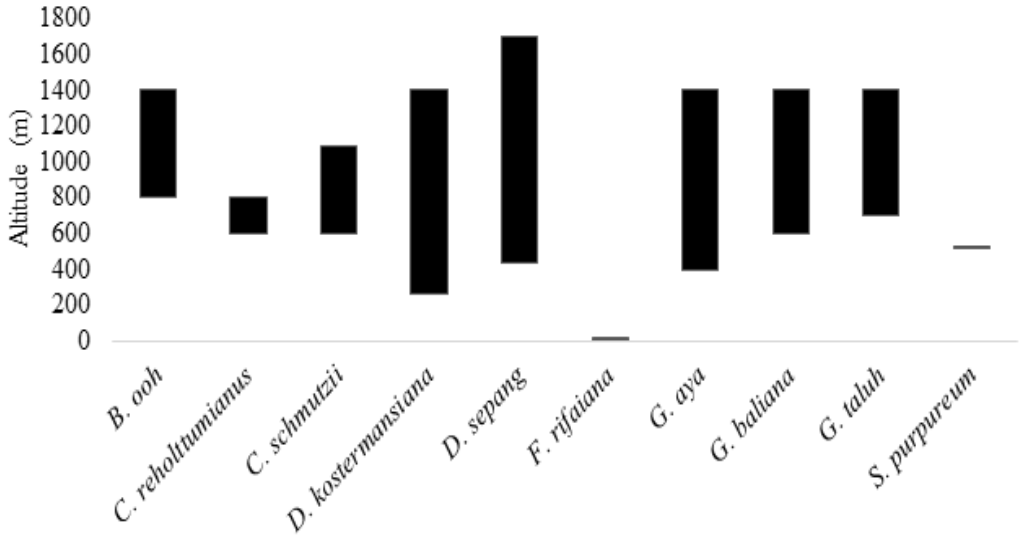

Figure 4. Altitude range of endemic bamboo in the Lesser Sunda Islands

Overall, the habitat of LSI’s endemic bamboo species is quite diverse, such as forests, bamboo forests, villages, botanical gardens, along a road, slopes, valleys, riverbanks, and around a lake (Figure 5). In its natural habitat, the slopes and riverbanks are the most common habitats for LSI’s endemic bamboo species. Bamboo has a flexible and robust culm, which allows it to bend without breaking (Ojo & Sadiku, 2023). This character means that it can adapt to the contours of a slope without being damaged. Inter-connected ramifying underground rhizome networks of sympodial bamboo bind the soil and prevent soil erosion (Kaushal et al., 2020), and prevent it from washing away during heavy rains, which is particularly important on slopes where water runoff and landslide can be a problem. Bamboo clumps are capable of retaining up to 25% of the rainfall that falls on the ground (Yasin & Priyanto, 2019) and have a high-water retention capacity (Dlamini et al., 2022), which means that bamboo can store water effectively. This character allows it to survive on slopes where water is scarce.

On the other hand, riverbanks tend to have high levels of moisture due to the proximity of water and nutrient-rich soil due to the regular deposition of sediment and organic matter, making bamboo well-suited to this environment. Besides, bamboo requires much sunlight to grow (Ferreira et al., 2020), and riverbanks tend to provide plenty of sun exposure due to no canopy around. Meanwhile, bamboo that grows in forests usually can seek sunlight above the forest canopy. For example, *Dinochloa*, a bamboo species commonly found in forests (Damayanto & Fefirenta, 2021), can grow in forests with its climbing habit towards the top of the forest canopy. Non-climbing bamboo species in the forest, on the other hand, tend to grow on riverbanks

or near footpaths where the canopy is more open, allowing for sufficient sunlight. In general, bamboo is a highly adaptable plant that can grow in a variety of conditions. This character makes it well-suited to diverse habitats where environmental conditions can be challenging.

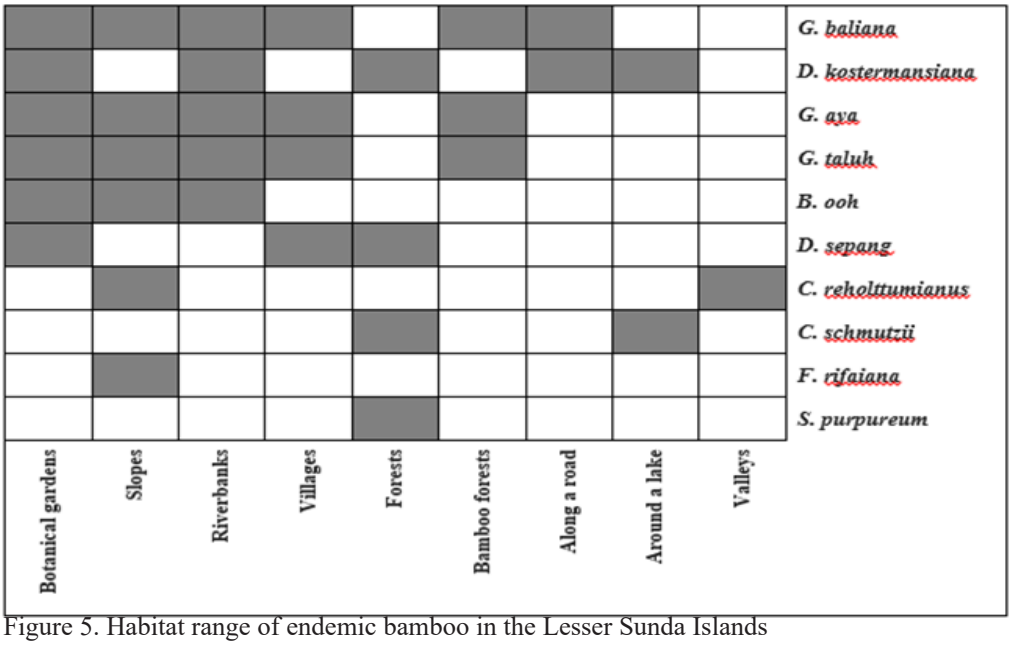

Figure 5. Habitat range of endemic bamboo in the Lesser Sunda Islands

All the endemic bamboo species in the LSI have local names (Table 1), indicating that they are well-known and widely used by the local people daily. These bamboos are used for various purposes, such as building materials, webbing (*gedek*), charcoal production, handicrafts (wind chimes), baskets, traditional Balinese baskets (*sokasi*), Balinese offerings (*penjor*), and flutes (Table 1). The massive utilization can have both positive and negative impacts on the existence of bamboo in nature. Residents, indirectly, usually make an effort to preserve bamboo that is often utilized so that it does not become extinct. On the other hand, over-harvesting of bamboo without conservation efforts can lead to the depletion of bamboo resources, which can have negative impacts on the extinction of bamboo, particularly endemic bamboo species.

Seven endemic bamboo species from LSI have now been classified as threatened species in the IUCN Red List (Table 1) with the following statuses: near threatened or NT (*C. schmutzii* and *D. kostermansiana*), vulnerable or VU (*C. reholttumianus*, *D. sepang*, *G. aya*, and *G. baliana*), and endangered or EN (*B. ooh*) (Chadburn, 2020a, 2020b, 2020c, 2021a, 2021b, 2021c, 2021d). One species (*S. purpureum*) was reported as data deficient (DD) (Chadburn, 2020d). Two other species (*F. rifaiana* and *G. taluh*) have not yet been evaluated. Near-threatened species may become endangered in the future but do not currently qualify as threatened; vulnerable species meet criteria A to E for vulnerability, indicating a significant risk of extinction; endangered species meet criteria A to E for endangerment, indicating a very high risk of extinction; and data deficient means there is not enough information to assess the risk of extinction based on the taxon's population status or distribution (IUCN, 2022).

Jurnal Biodjati 8(1):13–28, May 2023

JURNAL BIODJATI

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Fimbribambusa rifaiana is a very narrow endemic, known only from a single locality on Alor Island. The estimated extent of occurrence (EOO) is unidentified due to a single locality and the area of occupancy (AOO) is 4 km² (Table 1), which falls within a threatened category under B criteria of the IUCN Red List. Still, ongoing threats and declines are not specific. However, it is possible to be threatened by the area's modern development as this species occurs in slopes near a seashore which is an unprotected area, although the scale of the threat is difficult to quantify. The population and generation length of this bamboo is unknown. This bamboo was only described in 2020 (Widjaja, 2020), has not been searched for elsewhere, and needs more study. This bamboo could be considered a preventive assessment of near threatened (NT) as it is estimated to meet criteria B2 but just one sub-criteria (a).

Gigantochloa taluh is a very narrow endemic, known only from one village (Penglipuran) in Bangli, Bali. This species has been conserved in the "Eka Karya" Bali Botanical Garden in Tabanan, Bali. The EOO is unidentified due to a single locality, and AOO is 4 km² (Table 1) and falls within a threatened under B criteria of the IUCN Red List. This species occurs in the community bamboo forest, a protected and sustainably managed forest covering 45 (Agus, 2023 pers. comm.) to 75 hectares (Hendriyati, 2020). The community in Penglipuran Village is deeply committed to the awig-awig (traditional law) and strictly adheres to its rules, which prevent them from carrying out any actions that may cause harm to the ecosystem; therefore, the population of *G. taluh* is suspected to be relatively stable. The generation length and population of this bamboo are unknown. Therefore, this species is assessed as vulnerable (VU) under D2 criteria.

Although most endemic bamboo in the LSI is under threatened status, fortunately, some species have been conserved in the "Eka Karya" Bali Botanical Garden, and others grow in protected areas such as national park forests and community bamboo forests (Table 1). Some species (*D. sepang*, *C. reholttumianus*, and *C. schmutzii*), although not growing in protected areas such as national parks, grow in or near primary and secondary forests far enough from settlements (Figure 6). Human activity is generally less disturbed in forested areas than near settlements. Human activities, such as farming, logging, construction, and urbanization, can lead to habitat destruction, fragmentation, and degradation, which is detrimental to bamboo populations. On the other hand, *F. rifaiana* is reportedly only found around settlements (Figure 6) in Kalabahi, Alor Regency (Widjaja, 2020). This species may face habitat disturbance, as Kalabahi is the capital of the Alor Regency. The NT status assigned to *F. rifaiana* in this study may increase to a threatened level in the next few years due to the predicted loss of its habitat caused by urban development and land use change.

Dinochloa sepang was found growing in the forests on the slopes of Mt. Agung in Karangasem, Bali (Figure 6). Since Mt. Agung is an active volcano (Nugroho et al., 2020), *D. sepang* may face various challenges due to volcanic activity. An erupting volcano can release gases, ash, and magma, which can have a catastrophic impact on plants (Leggett, 2018). Moreover, the pyroclastic flow, a scorching surge of dense ash and gases that sweeps along the ground, can cause even more severe damage to plants (Lerner et al., 2022). Fortunately, *D. sepang* is also found in forest regions that are not situated on volcanic terrain and one area near settlements (Figure 6). However, forests can be impacted by hu-

mans, so it is vital to balance our needs with protecting these ecosystems and the services they provide.

On the other hand, *B. ooh*, *G. aya*, and *G. taluh*, which grow in areas near plantations and settlements (Figure 6), are vulnerable to a range of impacts. These species may face habitat loss due to land clearing for such purposes. Plantations and settlements can introduce non-native plant species or invasive species (Foggi et al., 2015) that may compete with endemic species for resources. Furthermore, pollution in these areas may have adverse effects on the growth of the endemic species (Işik, 2011). Another potential issue is over-harvesting, as they are known to be useful (Table 1). Fortunately, *B. ooh*, *G. aya*, and *G. taluh* are conserved in the "Eka Karya" Bali Botanical Garden (Kurniawan et al., 2022). Additionally, in their natural habitat, *G. aya* and *G. taluh* grow in protected community bamboo forests with strict traditional rules (Hendriyati, 2020; Agus, 2023 pers. comm.).

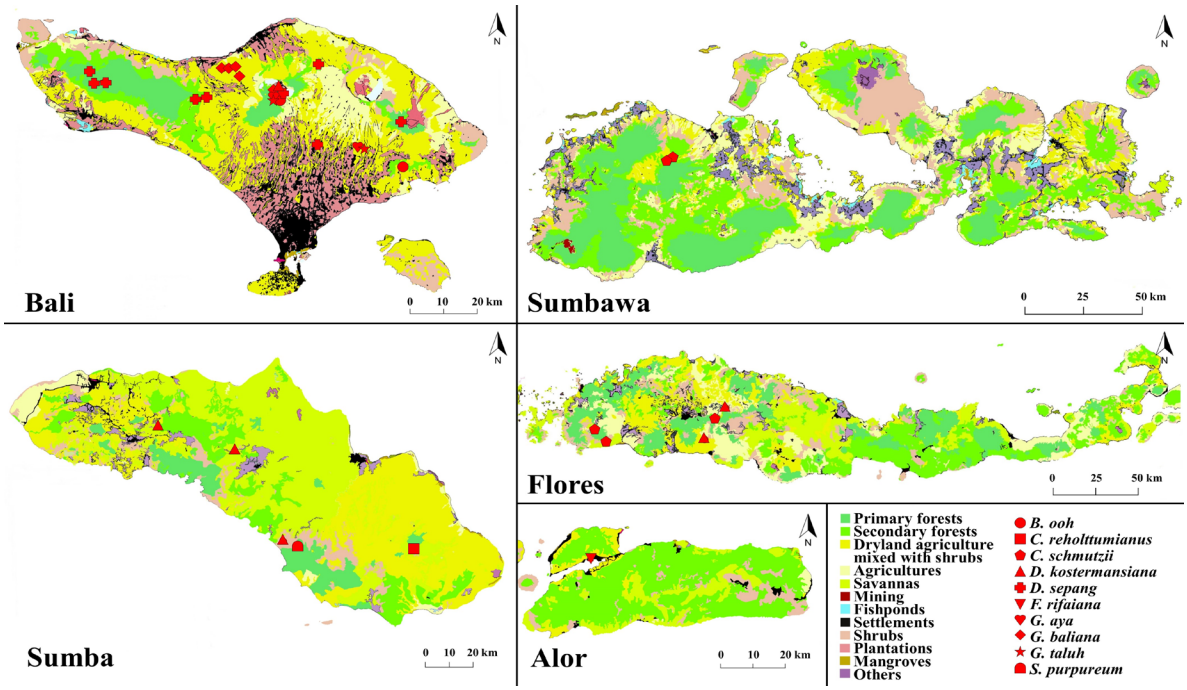

Figure 6. Overlapping maps of land covers and species distribution of endemic bamboo in the Lesser Sunda Islands

Identification key to the endemic bamboo species of the Lesser Sunda Islands

1 a. Culms climber or scrambling.....**2**

b. Culms erect.....**6**

2 a. Culms climber.....**3**

b. Culms scrambling.....**4**

3 a. Culm sheaths glabrous; auricles of culm sheath and leaf sheath rounded with bristles; leaf sheath ligules with bristles.....***Dinochloa kostermansiana***

b. Culm sheaths covered with white to pale brown hairs; auricles of culm sheath and leaf sheath inconspicu ous and glabrous; leaf sheath ligules glabrous.....***Dinochloa sepang***

4 a. Nodes with patella.....***Fimbribambusa rifaiana***
b. Nodes without patella.....**5**
5 a. Leaf sheath ligules entire and glabrous.....***Chloothamnus reholttumianus***
b. Leaf sheath ligules serrate and fringed.....***Chloothamnus schmutzii***
6 a. Branch complements with several sub-equal slender branches.....
.....***Schizostachyum purpureum***
b. Branch complements with a dominant primary branch and several smaller branches.....**7**
7 a. Branches grow close to the ground.....***Bambusa ooh***
b. Branches grow far from the ground.....**8**
8 a. Culm sheath ligules glabrous.....***Gigantochloa aya***
b. Culm sheath ligules with fine bristle.....**9**
9 a. Culm sheath appressed, auricles rim like, blade narrow triangular and erect when young and old.....
.....***Gigantochloa baliana***
b. Culm sheath caducous, auricles rounded to rim like, blade lanceolate and erect when young and deflexed when old.....***Gigantochloa taluh***

CONCLUSION

There are 10 endemic bamboo species in the LSI, namely *Bambusa ooh* from Bali (conservation status: endangered), *Chloothamnus reholttumianus* from Sumba (vulnerable), *C. schmutzii* from Sumbawa and Flores (near threatened), *Dinochloa kostermansiana* from Sumba and Flores (near threatened), *D. sepang* from Bali (vulnerable), *Fimbribambusa rifaiana* from Alor (near threatened), *Gigantochloa aya* from Bali (vulnerable), *G. baliana* from Bali (vulnerable), *G. taluh* from Bali (vulnerable), and *Schizostachyum purpureum* from Sumba (data deficient). They can be found at an altitude of 20–1700 m in various habitats, including forests, bamboo forests, villages, botanical gardens, along a road, slopes, valleys, riverbanks, and around a lake.

AUTHOR CONTRIBUTION

I.P.G.P.D. conceived and designed the research, conducted the explorations, collected and analyzed the data, interpreted the results, and wrote the first draft of the manuscript. H.R. conducted the explorations and wrote the manuscript. M. wrote the manuscript. T.C. designed the research and wrote the manuscript.

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CONFLICT OF INTEREST

We would like to declare that we have no conflicts of interest related to this research.

REFERENCES

Agung, I. G. A. M. S. & Hardini, Y. (1997). *Bamboo Diversity in Bali*. Denpasar: Faculty of Agriculture, University of Udayana.

Arinasa, I. B. K. (2005). Keanekaragaman dan Penggunaan Jenis-jenis Bambu di Desa Tigawasa, Bali. *Biodiversitas*, 6(1), 17–21. DOI: 10.13057/biodiv/d060104.

Arinasa, I. B. K. & Peneng, I. N. (2013). *Jenis-jenis Bambu di Bali dan Potensinya*. Jakarta: LIPI Press.

Arinasa, I. B. K. & Sujarwo, W. (2015). The Diversity of Endemic Bamboo in Bali and Conservation Efforts. *Bamboo Journal*, 29, 85–92.

Arinasa, I. B. K. & Widjaja, E. A. (2005). Bamboo Diversity in Bali, Indonesia. *Bamboo Journal*, 22, 8–16.

Chadburn, H. (2020a). *Chloothamnus reholttumianus.* The IUCN Red List of Threatened Species 2020: e. T167852518A167853419. DOI: 10.2305/IUCN.UK.2020-3.RLTS.T167852518A167853419.en.

Chadburn, H. (2020b). *Chloothamnus schmutzii*. The IUCN Red List of Threatened Species 2020: e.T167852532A167853424. DOI: 10.2305/IUCN.UK.2020-3.RLTS.T167852532A167853424.en.

Chadburn, H. (2020c). *Dinochloa kostermansiana*. The IUCN Red List of Threatened Species 2020: e. T167852558A167853429. DOI: 10.2305/IUCN.UK.2020-3.RLTS.T167852558A167853429.en.

Chadburn, H. (2020d). *Schizostachyum purpureum*. The IUCN Red List of Threatened Species 2020: e. T167853251A167853459. DOI: 10.2305/IUCN.UK.2020-3.RLTS.T167853251A167853459.en.

Chadburn, H. (2021a). *Bambusa ooh* (amended version of 2020 assessment). The IUCN Red List of Threatened Species 2021: e.T167852214A190232114. DOI: 10.2305/IUCN.UK.2021-1.RLTS.T167852214A190232114.en.

Chadburn, H. (2021b). *Dinochloa sepang* (amended version of 2020 assessment). The IUCN Red List of Threatened Species 2021: e.T167852693A190233073. DOI: 10.2305/IUCN.UK.2021-1.RLTS.T167852693A190233073.en.

Chadburn, H. (2021c). *Gigantochloa aya*. The IUCN Red List of Threatened Species 2021: e.T167852768A167853439. DOI: 10.2305/IUCN.UK.2021-3.RLTS.T167852768A167853439.en.

Chadburn, H. (2021d). *Gigantochloa baliana* (amended version of 2020 assessment). The IUCN Red List of Threatened Species 2021: e.T167852788A190233736. DOI: 10.2305/IUCN.UK.2021-1.RLTS.T167852788A190233736.en.

Damayanto, I. P. G. P. & Fefirenta, A. D. (2021). Pola Persebaran Marga Bambu di Indonesia. *Prosiding Biologi Achieving the Sustainable Development Goals with Biodiversity in Confronting*

Climate Change, 7(1), 24–41. DOI: 10.24252/psb.v7i1.22233.

Damayanto, I. P. G. P. & Irsyam, A. S. D. (2022). Penelusuran Spesimen Herbarium dalam Jaringan. *BACA: Jurnal Dokumentasi dan Informasi*, 43(1), 15–32. DOI: 10.14203/j.baca.v43i1.848.

Damayanto, I. P. G. P. & Widjaja, E. A. (2016). A New Species of *Schizostachyum* (Poaceae-Bambusoideae) from Sumba Island, Indonesia. *Reinwardtia*, 15(2), 119–122. DOI: 10.14203/reinwardtia.v15i2.2946.

Damayanto, I. P. G. P. (2016). Lulu Ura Bambu Liar Merambat Endemik Nusa Tenggara Timur. *Buletin Kakatua*, 1, 14–16.

Damayanto, I. P. G. P. (2017). Climbing Bamboos of Lesser Sunda Islands, Indonesia. *Proceedings The 1st SATREPS Conference*, 1, 90–93.

Damayanto, I. P. G. P., Arinasa, I. B. K., Tirta, I. G. & Widjaja, E. A. (2020a). A New record of *Chloothamnus* Buse (Poaceae: Bambusoideae) from Sumbawa Island and Notes on the Genus in Malesia. *Floribunda*, 6(4), 127–132. DOI: 10.32556/floribunda.v6i4.2020.282.

Damayanto, I. P. G. P., Fastanti, F. S. & Dalimunthe, S. H. (2020b). Pemanfaatan Portal Basis Data Daring dalam Validasi Nama Ilmiah Jenis dan Suku Tumbuhan. *Berkala Ilmu Perpustakaan dan Informasi*, 16(2), 170–183. DOI: 10.22146/bip.v16i2.770.

Damayanto, I. P. G. P., Mahendra, T. & Rosalina, D. (2018). Bamboo Diversity at Laiwangi-Wanggameti National Park, Sumba, Indonesia. *Buletin Kebun Raya*, 21(1), 45–52. DOI: 10.14203/bkr.v21i1.430.

Damayanto, I. P. G. P., Rustiami, H., Miftahudin, & Chikmawati, T. (2020c). A Synopsis of *Bambusoideae* (Poaceae) in Lombok, Indonesia. *Biodiversitas*, 21(10), 4489–4500. DOI: 10.13057/biodiv/d211004.

Djarwaningsih, T., Sunarti, S. & Kramadibrata, K. (2002). *Panduan Pengolahan dan Pengelolaan Material Herbarium serta Pegendalian Hama Terpadu di Herbarium Bogoriense*. Bogor: Herbarium Bogoriense, Bidang Botani, Pusat Penelitian Biologi – LIPI.

Dlamini, L. C., Fakudze, S., Makombe, G. G., Muse, S. & Zhu, J. (2022). Bamboo as a Valuable Resource and its Utilization in Historical and Modern-day China. *BioResources*, 17(1), 1926–1938. DOI: 10.15376/biores.17.1.Dlamini.

Dransfield, S. & Widjaja, E. A. (1995). *Plant Resources of South-East Asia No. 7 Bamboos*. Leiden: Backhuys Publishers.

Dransfield, S. (1980). Three New Malesian Species of Gramineae. *Reinwardtia*, 9(4), 386–392. DOI: 10.14203/reinwardtia.v9i4.916.

Dransfield, S. (1996). New Species of *Dinochloa* (Gramineae-Bambusoideae) in Malesia and Notes on the Genus. *Kew Bulletin*, 51(1), 103–117. DOI: 10.2307/4118748.

Ferreira, E., Kalliola, R. & Ruokolainen, K. (2020). Bamboo, Climate Change and Forest Use: a Critical Combination for Southwestern Amazonian Forests?. *Ambio*, 49, 1353–1363. DOI: 10.1007/s13280-019-01299-3.

Foggi, B., Viciani, D., Baldini, R., Carta, A. & Guidi, T. (2015). Conservation Assessment of the Endemic Plants of the Tuscan Archipelago, Italy. *Oryx*, 49(1), 118–126. DOI: 10.1017/S0030605313000288.

Ghorbanalizadeh, A. & Akhani, H. (2022). Plant Diversity of *Hyrcanian relict* forests: an Annotated Checklist, Chorology and Threat Categories of Endem-

ic and Near Endemic Vascular Plant Species. *Plant Diversity*, 44(1), 39–69. DOI: 10.1016/j.pld.2021.07.005.

Hendriyati, L. (2020). Upaya Masyarakat di Desa Wisata Penglipuran dalam Menjalankan Sapta Pesona. *Journal of Tourism and Economic*, 3(1), 49–57. DOI: 10.36594/jtec.v3i1.54.

Işik, K. (2011). Rare and Endemic Species: Why are They Prone to Extinction? *Turkish Journal of Botany*, 35(4), 411–417. DOI: 10.3906/bot-1012-90.

IUCN. (2022). Guidelines for Using the IUCN Red List Categories and Criteria. Version 15.1. Prepared by the Standards and Petitions Committee. Retrieved from https://nc.iucnredlist.org/redlist/content/attachment_files/RedList-Guidelines.pdf.

Kaushal, R., Tewari, S., Banik, R. L., Thapliyal, S. D., Singh, I., Reza, S. & Durai, J. (2020). Root Distribution and Soil Properties Under 12-year Old Sympodial Bamboo Plantation in Central Himalayan Tarai Region, India. *Agroforestry Systems*, 94, 917–932. DOI: 10.1007/s10457-019-00459-4.

Kurniawan, A., Sumerta, I. M., Sudiatna, I. N., Suriani, N. M., Merriansyah, H., Arnawa, I. W., Putri, D. M. S. & Iryadi, R. (2022). *An Alphabetical List of Plant Species Cultivated in "Eka Karya" Bali Botanic Garden*. Jakarta: BRIN Publishing.

Lerner, G. A., Jenkins, S. F., Charbonnier, S. J., Komorowski, J. C. & Baxter, P. J. (2020). The Hazards of Unconfined Pyroclastic Density Currents: a New Synthesis and Classification According to Their Deposits, Dynamics, and Thermal and Impact Characteristics. *Journal of Volcanology and Geothermal Research*, 421(107429), 1–20. DOI: 10.1016/j.jvolgeores.2021.107429.

Leggett, R. (2018). Plants & Animals Around Volcanoes. Retrieved from https://sciencing.com/plants-animals-around-volcanoes-8259688.html.

Mahmoodi, S., Heydari, M., Ahmadi, K., Khwarahm, N. R., Karami, O., Almasieh, K., Naderi, B., Bernard, P. & Mosavi, A. (2022). The Current and Future Potential Geographical Distribution of *Nepeta crispa* Willd., an Endemic, Rare and Threatened Aromatic Plant of Iran: Implications for Ecological Conservation and Restoration. *Ecological Indicators*, 137(108752), 1–11. DOI: 10.1016/j.ecolind.2022.108752.

Manes, S., Costello, M. J., Beckett, H., Debnath, A., Devenish-Nelson, E., Grey, K., Jenkins, R., Khan, T. M., Kiessling, W., Krause, C., Maharaj, S. S., Midgley, G. F., Price, J., Talukdar, G. & Vale, M. M. (2021). Endemism Increases Species' Climate Change Risk in Areas of Global Biodiversity Importance. *Biological Conservation*, 257(109070), 1–11. DOI: 10.1016/j.biocon.2021.109070.

Muzakki, F. A. (2020). Keberagaman Bambu Marga *Schizostachyum* Nees di Jawa. *Thesis*. Bogor: Institut Pertanina Bogor.

Myers, N., Mittermeier, R., Mittermeier, C., da Fonseca, G. A. B. & Ken, J. (2000). Biodiversity Hotspots for Conservation Priorities. *Nature,* 403, 853–858. DOI: 10.1038/35002501.

Nugroho, R., Rizkiah, R. & Setiyoko, A. (2020). Studi Pengaruh Erupsi Abu Vulkanik Gunung Agung Terhadap Hasil Pengukuran Partikel Tersuspensi. *Sainteks: Jurnal Sain dan Teknik*, 2(2), 72–82. DOI: 10.37577/sainteks.v2i2.284.

Ojo, A. R. & Sadiku, N. A. (2023). Slenderness Coefficient and Growth Characteristics

of Africa Giant Bamboo: *Bambusa vulgaris* Schrad. ex J.C. Wendl. *Advances in Bamboo Science*, 2(100017), 1–7. DOI: 10.1016/j.bamboo.2023.100017.

Pinto-Junior, H. V., Villa, P. M., Pereira, M. C. A. & de Menezes, L. F. T. (2020). The Pattern of High Plant Diversity of *Neotropical inselbergs*: Highlighting Endemic, Threatened and Unique Species. *Acta Botanica Brasilica*, 34(4), 645–661. DOI: 10.1590/0102-33062020abb0129.

Retnowati, A. & Rugayah. (2019). *Keanekaragaman Tumbuhan dan Jamur Indonesia*. In A. Retnowati, Rugayah, J. S. Rahajoe & D. Arifiani (Eds.), Status Keanekaragaman Hayati Indonesia: Kekayaan Jenis Tumbuhan dan Jamur Indonesia (pp. 1–14). Jakarta: LIPI Press.

Rugayah, Retnowati, A., Windadri, F. I. & Hidayat, A. (2004). *Pengumpulan Data Taksonomi.* In: Rugayah, E. A. Widjaja & Praptiwi (Eds.), Pedoman Pengumpulan Data Keanekaragaman Flora (pp. 5–42). Bogor: Pusat Penelitian Biologi – LIPI.

Soenarko, S. (1977). A New Species of *Nastus* Nees (Gramineae) from Sumba. *The Garden's Bulletin Singapore*, 30, 17–19.

Steenis-Kruseman, M. J. V. (1950). Malaysian Plant Collectors and Collections. *Flora Malesiana*, 1(1), 1–639.

Vorontsova, M. S., Clark, L. G., Dransfield, J., Govaerts, R. H. A. & Baker, W. J. (2016). World Checklist of Bamboos and Rattans. *INBAR Technical Report*, 37, 1–454.

Widjaja, E. A. & Karsono. (2005). Keanekaragaman Bambu di Pulau Sumba. *Biodiversitas*, 6(2), 95–99. DOI: 10.13057/biodiv/d060205.

Widjaja, E. A. & Wong, K. M. (2016). New Combinations in *Chloothamnus* (Poaceae: Bambusoideae), a Genus of Malesian Bamboos Formerly Confused with *Nastus*. *Sandakania*, 22, 37–40.

Widjaja, E. A. (1987). A Revision of Malesian *Gigantochloa* (Poaceae-Bambusoideae). *Reindwartia*, 10(3), 291–380. DOI: 10.14203/reinwardtia.v10i3.274.

Widjaja, E. A. (1997). New Taxa in Indonesian Bamboos. *Reindwartia*, 11(2), 57–152. DOI: 10.14203/reinwardtia.v11i2.588.

Widjaja, E. A. (2001). *Identikit Jenis-jenis Bambu di Kepulauan Sunda Kecil.* Bogor: Pusat Penelitian dan Pengembangan Biologi – LIPI.

Widjaja, E. A. (2019). *The Spectacular Indonesian Bamboos*. Jakarta: Polagrade.

Widjaja, E. A. (2020). Notes on *Fimbribambusa* Widjaja, with a New Species from the Lesser Sunda Islands. *Reinwardtia*, 19(1), 55–59. DOI: 10.14203/reinwardtia.v19i1.3838.

Widjaja, E. A., Astuti, I. P. & Arinasa, I. B. K. (2004). New Species of Bamboos (Poaceae-Bambusoideae) from Bali. *Reinwardtia*, 12(2), 199–204. DOI: 10.14203/reinwardtia.v12i2.73.

Widjaja, E. A., Astuti, I. P., Arinasa, I. B. K. & Sumantera, I. W. (2005). *Identikit Bambu di Bali*. Bogor: Indonesia, Bidang Botani, Pusat Penelitian Biologi – LIPI.

Widjaja, E. A., Rahayuningsih, Y., Rahajoe, J. S., Ubaidillah, R., Maryanto, I., Walujo, E. B. & Semiadi, G. (2014). *Kekinian Keanekaragaman Hayati Indonesia 2014*. Jakarta: LIPI Press.

Yasin, I. & Priyanto, A. (2019) Analysis of Bamboo Mechanical Properties as Construction Eco-friendly Materials to Minimizing Global Warming Effect. *IOP Conference Series: Materials Science and Engineering*, 535(012001), 1–9. DOI: 10.1088/1757-899X/535/1/012001.