REINWARDTIA

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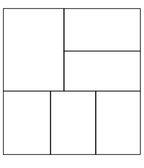

Cover images: *Begonia tanggamusensis* Girm. & M.Hughes. Top left: Habit. Top right: Infructescence. Middle right: Ripe fruit. Below left: Young inflorescence and open staminate flower. Below middle: Young inflorescence with bracts subtending. Below right: Pistillate flower. Photos by Mark Hughes.

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DIVERSITY OF MANGROVES AND ASSOCIATED PLANTS IN MANDANGISIAO ESTUARY, MISAMIS ORIENTAL, PHILIPPINES

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ABSTRACT
SITOY, W. B. O. & BUENAVISTA, D. P. 2024. Diversity of mangroves and associated plants in Mandangisiao Estuary, Misamis Oriental, Philippines. *Reinwardtia* 23(1): 1–14. — The study aimed to assess the diversity status of mangroves and associates. Four transect lines were established perpendicular to the shoreline, ranging from 20 to 100 meters based on mangrove stand size. Along these transects, three 10 m × 10 m quadrat plots were set up to evaluate mangrove trees, and within each quadrat, a 2 m × 2 m regeneration plot was established. The study calculated the diversity indices, such as relative frequency, relative density, and relative dominance to determine the species importance value. A total of four mangrove species and two associated plants were identified, representing three mangrove families and three genera, as well as three plant families and three genera for associated plants. The recorded species included *Avicennia marina, Nypa fruticans, Rhizophora mucronata, Sonneratia caseolaris, Acanthus ebracteatus*, and *Acrostichum speciosum*. The overall diversity value of the mangroves and associated plants was 0.87, indicating relatively low species richness. The true mangroves, *Rhizophora mucronata* exhibited the highest values for relative density (68.07%), while *Nypa fruticans* is the highest in terms of relative dominance (42.20%). Both have the same highest value in relative frequency (32.43%). All in all, the highest species importance value for true mangroves is *Rhizophora mucronata* with 126.23%. In associated plants, highest value of relative density and relative frequency belongs to *Acanthus ebracteatus* with 58% and 60%, respectively. Subsequently, the highest species importance value for associated plants is 118% for *Acanthus ebracteatus*. The study concluded that the Mandangisiao Estuary in Jasaan, Misamis Oriental has a limited species diversity, contrary to the initial hypothesis. Furthermore, the mangrove forest in the estuary faces potential threats from garbage dumping, tree cutting, boat mooring, and human encroachment, despite all the recorded species having a Least Concern conservation status.

Key words: *Avicennia*, conservation, mangrove, Mindanao, *Nypa*, *Rhizophora*.

ABSTRAK
SITOY, W. B. O. & BUENAVISTA, D. P. 2024. Keanekaragaman mangrove dan tumbuhan terkait di Muara Mandangisiao, Misamis Oriental, Filipina. *Reinwardtia* 23(1): 1–14. — Penelitian ini bertujuan untuk mengkaji status keanekaragaman mangrove dan asosiasinya. Empat garis transek dibuat tegak lurus terhadap garis pantai, berkisar antara 20 hingga 100 meter berdasarkan ukuran tegakan mangrove. Sepanjang transek ini, dibuat tiga plot kuadrat berukuran 10 m × 10 m untuk mengevaluasi pohon bakau, dan di setiap kuadrat, dibuat plot regenerasi berukuran 2 m × 2 m. Penelitian ini menghitung indeks keanekaragaman, seperti frekuensi relatif, kepadatan relatif, dominasi relatif untuk menentukan nilai kepentingan jenis. Sebanyak empat jenis mangrove dan dua tumbuhan berasosiasi telah diidentifikasi, mewakili tiga suku mangrove dan tiga marga, serta tiga suku tumbuhan dan tiga marga tumbuhan berasosiasi. Jenis yang tercatat termasuk *Avicennia marina, Nypa fruticans, Rhizophora mucronata, Sonneratia caseolaris, Acanthus ebracteatus,* dan *Acrostichum speciosum*. Nilai keanekaragaman mangrove dan tumbuhan terkait secara keseluruhan adalah 0,87, yang menunjukkan kekayaan jenis yang relatif rendah. Mangrove sejati, *Rhizophora mucronata* menunjukkan nilai kepadatan relatif tertinggi (68,07%), sedangkan *Nypa fruticans* memiliki nilai dominansi relatif tertinggi (42,20%). Keduanya mempunyai nilai frekuensi relatif tertinggi yang sama (32,43%). Secara keseluruhan, nilai penting jenis tertinggi bagi mangrove sejati adalah *Rhizophora mucronata* sebesar 126,23%. Pada tumbuhan ber-asosiasi, nilai kerapatan relatif dan frekuensi relatif tertinggi dimiliki oleh *Acanthus ebracteatus* masing-masing sebesar 58% dan 60%. Selanjutnya, nilai penting jenis tertinggi untuk tumbuhan berasosiasi adalah 118% untuk *Acanthus ebracteatus*. Penelitian menyimpulkan bahwa Muara Mandisiao di Jasaan, Misamis Oriental memiliki keanekaragaman jenis yang terbatas, bertentangan dengan hipotesis awal. Selain itu, hutan mangrove di muara juga menghadapi potensi ancaman dari pembuangan sampah, penebangan pohon, tambatan kapal, dan perambahan manusia, meskipun semua jenis yang tercatat memiliki status konservasi risiko rendah.

Kata kunci: *Avicennia,* konservasi, Mindanao, mangrove, *Nypa*, *Rhizophora*.

INTRODUCTION

Along the tropical, subtropical, and some temperate coasts, intertidal mangrove forests can be found, frequently coexisting with dense human populations (Friess *et al.*, 2019). The mangrove forest is referred to as the "rainforest of the sea", and like the upland rainforest, it supports the coasts economically and ecologically (Mendoza, 2017). Mangroves are essential components of an ecosystem because they provide food for numerous fish, insects, and birds as well as protection from coastal hazards (Alongi, 2002). It also offers crucial ecological services to hundreds of millions of people, including fish, lumber, fuelwood, coastal protection, pollution management, and cultural and spiritual values (Barbier *et al.*, 2010; Buenavista & Purnobasuki, 2023). Mangroves are now firmly on the international agenda for climate mitigation and adaptation as a result of the recent vigorous promotion of their role in carbon sequestration (Howard *et al.*, 2017).

However, due to human activities that pose a serious threat to the environment and the variety of life in mangrove areas, the number of mangroves worldwide has been declining at an alarming rate (Cudiamat & Rodriguez, 2017). Mangroves are also seriously threatened throughout a significant portion of their range due to their location in an area with rising human population concentrations and competing coastal management goals. Large-scale mangrove destruction is a result of nearby factors like aquaculture, agriculture, and urban expansion (Richards & Friess, 2016; Thomas *et al.*, 2017), while pollution and resource over exploitation further harm mangroves (Lee *et al.*, 2006). At larger scales, mangroves are affected by long-term processes such as relative sea-level rise and sea-level variations connected to climate oscillations (Lovelock *et al.*, 2015; Duke *et al.*, 2017). These effects have significant repercussions for the vulnerability of coastal populations who depend on mangrove resources.

Approximately 70 species of mangrove (Polidoro *et al.*, 2010) and 60 species of mangrove associates are known worldwide (Tomlinson, 1986). In the Philippines, 39 species of mangroves are known to exist (Nieves & Bradecina, 2020). Unfortunately, the Philippines has lost over 75% of its mangrove habitat during the past few decades, with the majority disappearing between 1950 and 1990 (Primavera, 2000; Samson & Rollon, 2008). In a nation where more than half of its 1,500 municipalities and 42,000 towns rely on coastal resources, the loss of mangrove habitat directly affects its populace (Primavera, 2000). Presently, the Philippines has a 0.5% annual mangrove loss estimated (Fries *et al.*, 2019). As such, the need for conservation is increasingly important as a result of anthropogenic alterations to the natural environment that have caused disturbing rates of biodiversity loss (Beger *et al.*, 2014). Due to the Philippines' reputation as a biodiversity hotspot, identifying the gaps and biases in the country's biodiversity record can be a crucial first step in determining the most important research area for conservation applications (Berba & Matias, 2022).

The Municipality of Jasaan in the province of Misamis Oriental, Mindanao Island is one of the mangrove areas that is still ecologically understudied. Some of the mangroves in the area are vulnerable to hazards, such as being cut down for various purposes that could endanger nearby species. Moreover, there is no published information on studies on mangroves and their plant associates in Mandangisiao Estuary, Jasaan. Thus, this research is being carried out.

MATERIALS AND METHODS

The Municipality of Jasaan, Misamis Oriental, Mindanao, Philippines is geographically located at 8°38'56.4"N 124°45'20.7"E with an elevation of 25.9 meters (85.0 feet) above sea level (m asl). The study was carried out in the natural mangrove stands in Mandangisiao Estuary in Jasaan. The study was conducted from February to April 2023 (Figs. 1 & 2).

The field sampling followed the Participatory Coastal Resource Assessment Training Guide by Deguit *et al.* (2004) wherein four (4) transect lines were laid perpendicular to the shoreline ranging from 20 to 100 meters, depending on the size of the mangrove stands. The transect lines were placed where the mangrove forest begins and end where the forest ends. After which, a series of three (3) 10 m × 10 m quadrat plots were established along the transect line, for the assessment of mangrove trees (DENR-EMB Guidelines on the Assessment of Coastal and Marine Ecosystems, 2017). In each quadrat, a 2 m × 2 m regeneration plot were also established, this is to measure the seedlings and saplings (less than 3 cm DBH) in each plot. The 10 m × 10 m quadrats plots were laid with 50 m distance in between depending on vegetation characteristics, landscape, and extend of mangrove (Fig. 3).

The voucher plant specimens were collected and preserved using the method of Morse (2000). Using a pruning shear, three to five representative specimens bearing flowers and/or fruits material were clipped off from the mangroves during collection. The acquired sample specimens were placed in a clean container or plastic bag with their field information to avoid damage and dehydration. Using the field data sheet, characters of the specimen were recorded including the coordinates, elevation, and seasonal characters. Tags with accompanying specimen number were attached to the plant collected. Relevant information such as plot

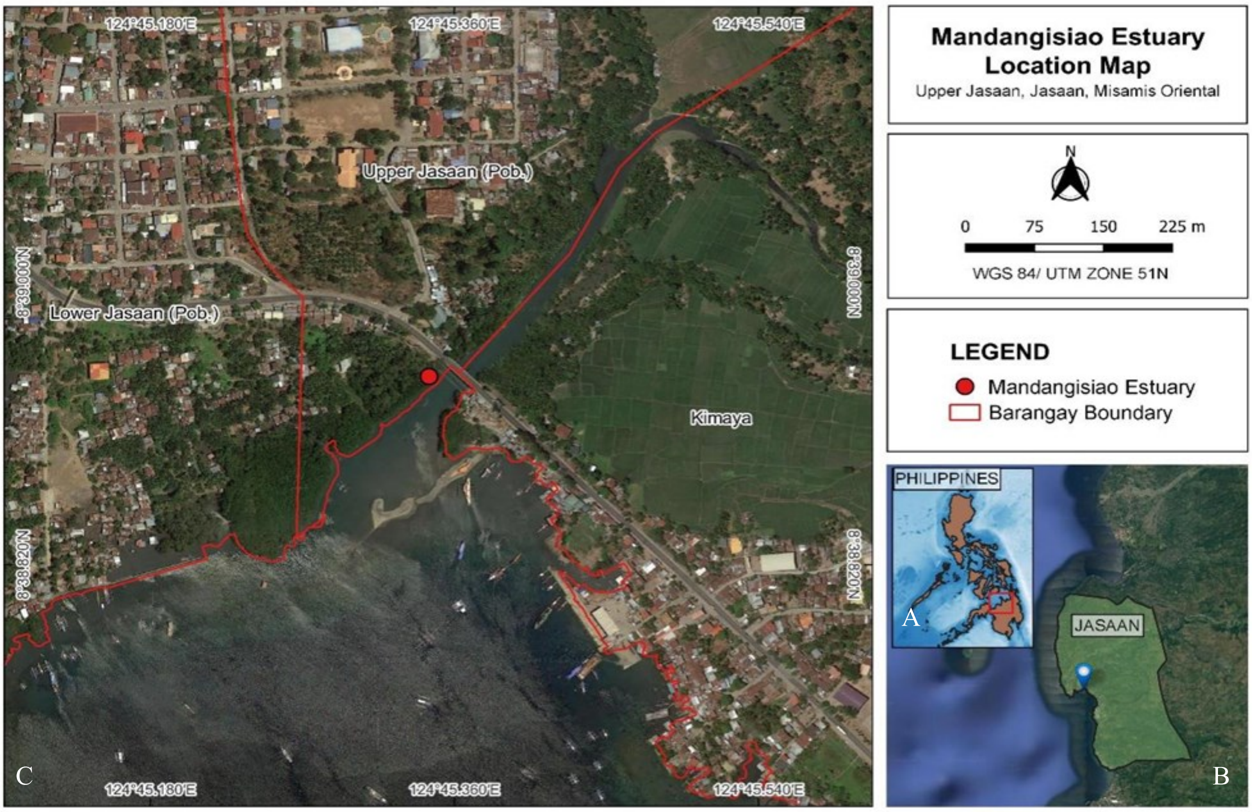

Fig. 1. Location map of the study site. A. Map of the Philippines. B. Map of the Municipality of Jasaan, Misamis Oriental. C. Map of the Mandangisiao Estuary, Upper Jasaan, Jasaan, Misamis Oriental.

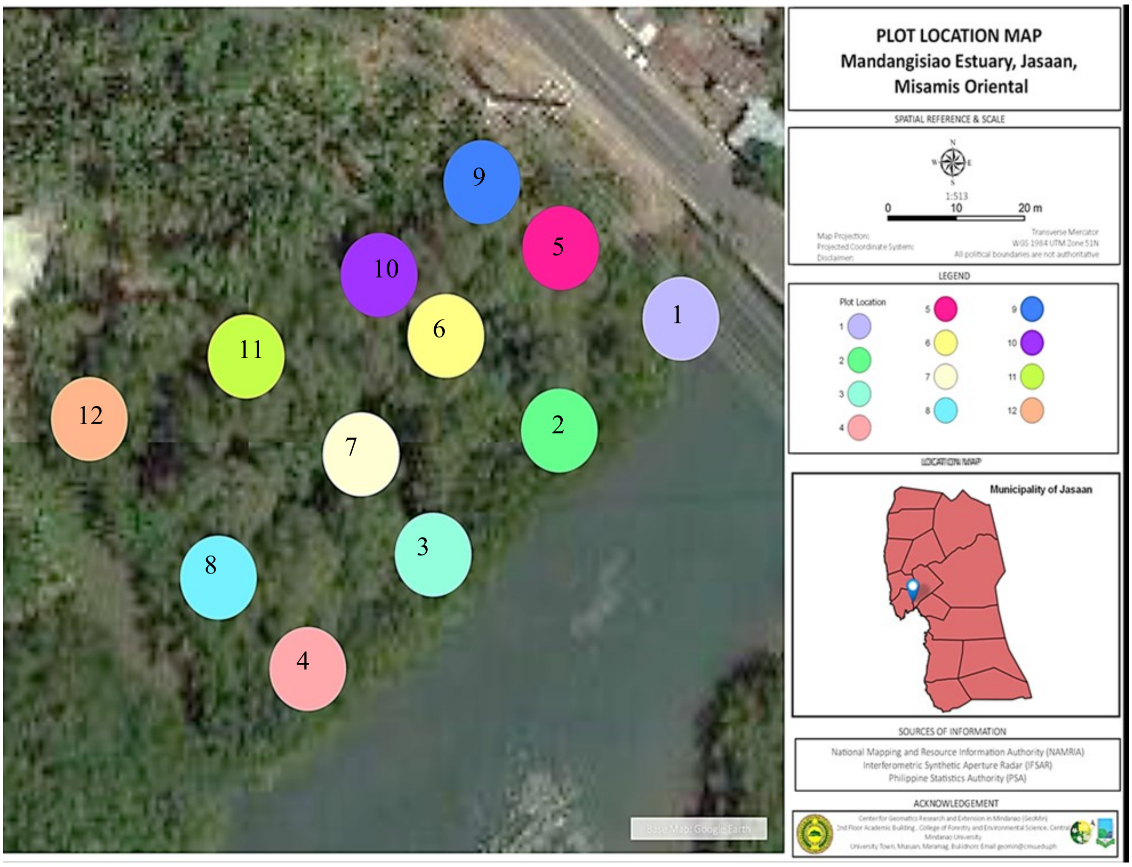

Fig. 2. Location map of the study site showing the twelve (12) sampling plots.

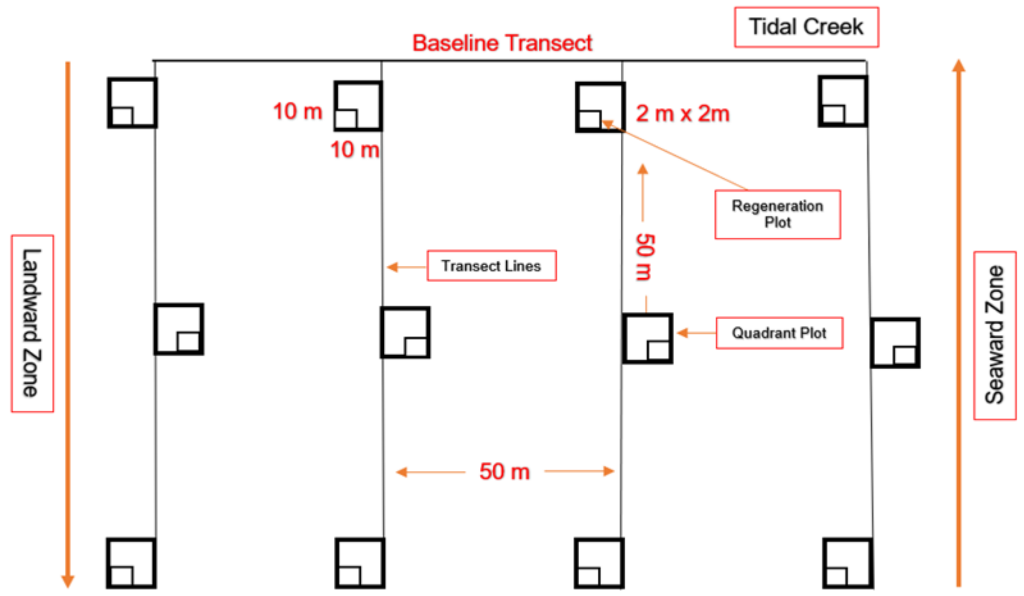

Fig. 3. Diagram showing the layout of the transect lines and plots modified from Deguit *et al.* (2004).

number and date were recorded in the field notebook and photos of plant parts were also taken. Mangroves were counted inside the plot, and measurements of their diameter at breast height (dbh), basal area, and density were taken. The specimens that were collected are subjected to wet mounting, which involves treating plants with denatured alcohol to preserve and destroy organisms present in the plant samples. Collected flowers were then preserved in spirit collection. The pile of sample specimens was pressed using normal size wooden presser with straw rope to tighten the presser after the mounting technique was done. Plant samples were then sundried. Voucher specimens were deposited in Central Mindanao University Museum.

Mangroves were initially taxonomically identified and classified by examining its vegetative and reproductive morphological structures such as the leaves, roots, flowers, and even fruit using the field guide of Primavera *et al.* (2004) and Primavera & Dianala (2009). The pre-identified mangroves were taxonomically verified and confirmed by Forester Lowell G. Aribal of Central Mindanao University and Dr. Jurgenne Primavera, Chief Mangrove Scientific Advisor of the Zoological Society of London. The collected data within the 10 m × 10 m sampling plots was used in the computation of the following diversity indices (Barbour *et al.*, 1987). The Species Importance Value (SIV) index shows how each species contributes to the community. In this study, the relative density, relative frequency, and relative dominance data were added to determine the SIV of the mangrove trees, which have a maximum value of 300 (Cintrón & Schaeffer-Novelli, 1984). On the other hand, for understory mangrove associates, the data on relative density and relative frequency were summed up to determine the SIV. The diversity index value provides a quantitative analysis of the species richness and distribution within the mangrove habitat. The diversity values were classified based on a scale of Gevaña & Pampolina (2009). In the assessment of the conservation status, the IUCN Red List of Threatened Species (Version 2022-1) and DENR Administrative Order No. 11 series of 2017 known as the Updated List of Threatened Philippine Plants and their Categories were used.

RESULTS

Species Composition

A total of four mangrove species and two mangrove associates were recorded in the mangrove forest of Mandangisiao Estuary in Jasaan, Misamis Oriental (Table 1). These mangrove species and mangrove associates belonged to five botanical families namely, Acanthaceae (2 species), Arecaceae (1 species), Lythraceae (1 species), Rhizophoraceae (1 species), and Pteridaceae (1 species) (Table 1). The four mangrove species found in the Mandangisiao Estuary are clearly

Table 1. List of mangroves and associated plants observed in Mandangisiao Estuary, Jasaan, Misamis Oriental.

Family	Scientific name	Common name
I. Mangroves		
Acanthaceae	*Avicennia marina* (Forssk.) Vierh.	Piapi
Arecaceae	*Nypa fruticans* Wurmb	Nipa
Lythraceae	*Sonneratia caseolaris* (L.) Engl.	Pedada
Rhizophoraceae	*Rhizophora mucronata* Lam.	Bakhaw babae
II. Associated Plants		
Acanthaceae	*Acanthus ebracteatus* Vahl.	Lagiwliw
Pteridaceae	*Acrostichum speciosum* Willd.	Palaypay

Table 2. Occurrence of mangrove species and associated plants in twelve sampling plots of Mandangisiao Estuary, Jasaan, Misamis Oriental.

Family and Species	Plots											
	1	2	3	4	5	6	7	8	9	10	11	12
I. Mangroves												
A. Acanthaceae												
Avicennia marina (Forssk.)	+					+			+	+	+	+
B. Arecaceae												
Nypa fruticans Wurmb	+	+	+	+	+	+	+	+	+	+	+	+
C. Lythraceae												
Sonneratia caseolaris (L.) Engl.					+	+	+	+	+		+	+
D. Rhizophoraceae												
Rhizophora mucronata Lam.	+	+	+	+	+	+	+	+	+	+	+	+
II. Associated Plants												
A. Acanthaceae												
Acanthus ebracteatus Vahl					+	+		+		+	+	+
B. Pteridaceae												
Acrostichum speciosum Willd.					+		+		+	+		

fewer than the eight mangrove species found in the entire municipality of Jasaan, which include three species of the genus *Rhizophora*, two species each of the genus *Avicennia* and *Sonneratia*, and one species of the genus *Bruguiera.*

Among the recorded species of mangroves and associated plants, the family Acanthaceae was the most represented plant group with two species namely, *Avicennia marina* and *Acanthus ebracteatus*. Only one species was recorded to belong to the Arecaceae, namely *Nypa fruticans*. Likewise, in the families Lythraceae, Rhizophoraceae, and Pteridaceae, each with a single species*: Sonneratia caseolaris, Rhizophora mucronata,* and *Acrostichum speciosum*, respectively (Table 2).

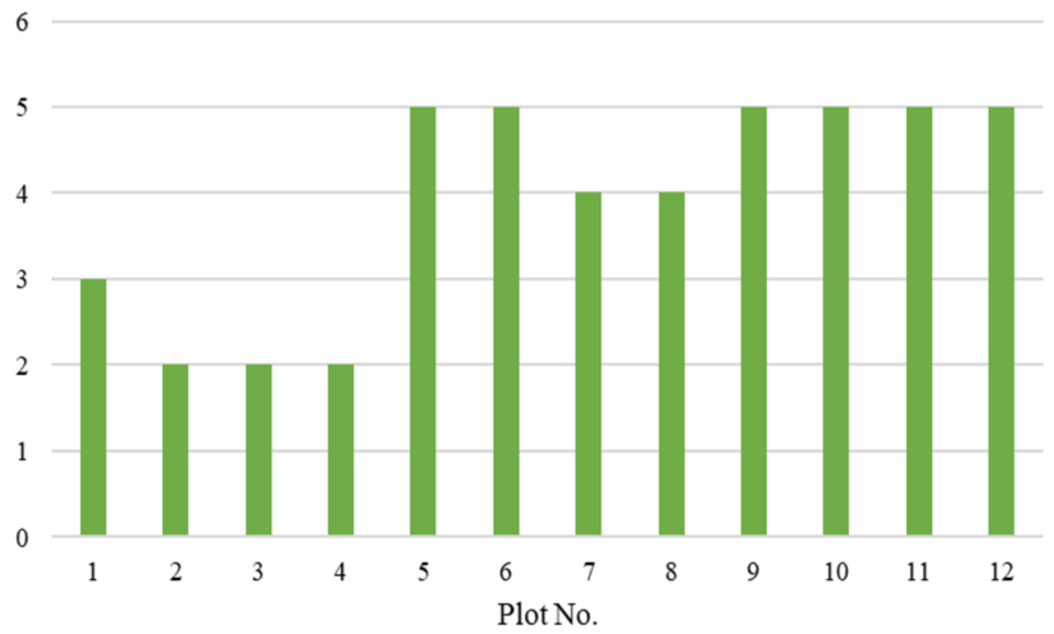

Fig. 4. Bar graph showing the number of species found in plots.

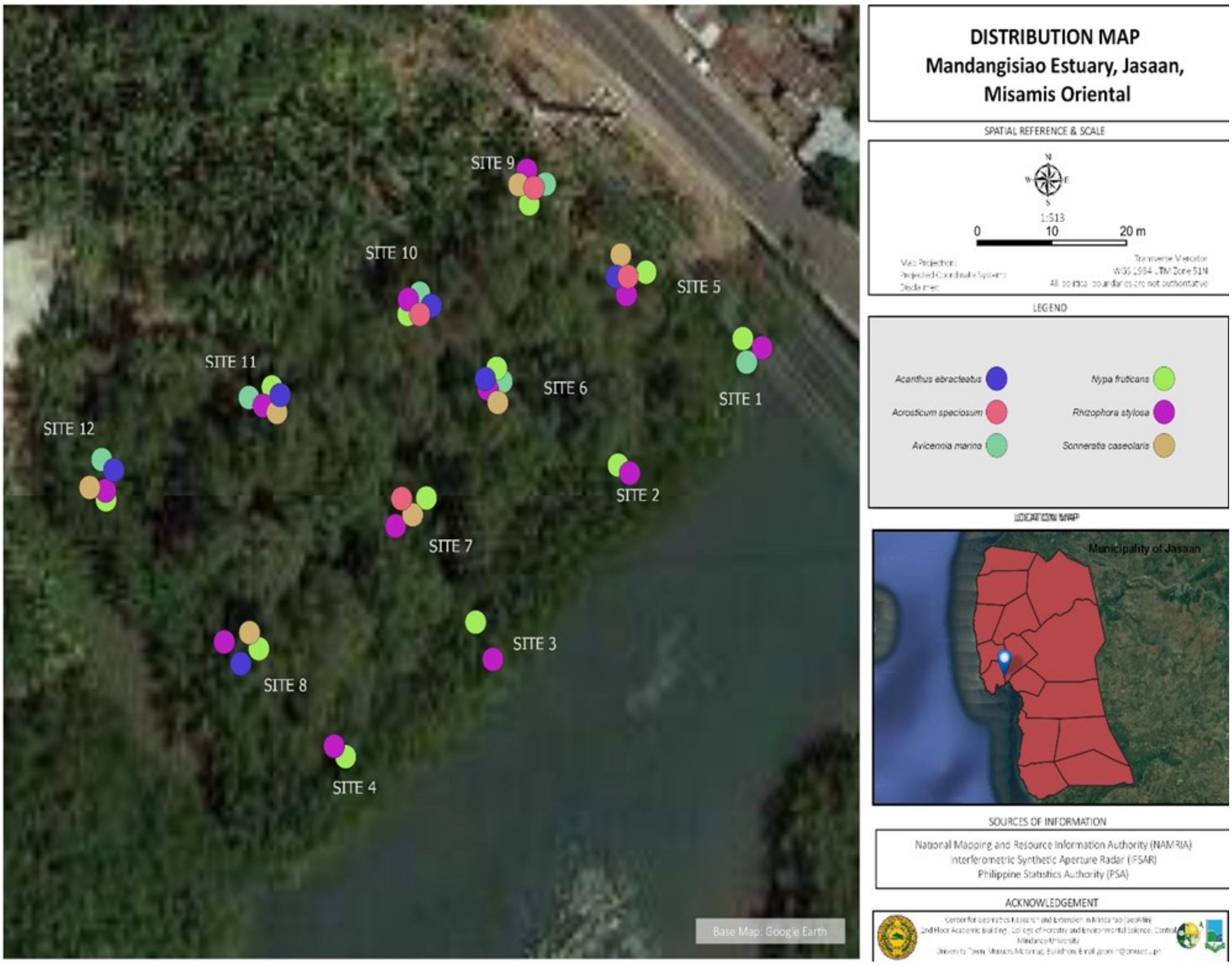

Fig. 5. Distribution map of species found in each sampling plot in Mandangisiao Estuary, Jasaan, Misamis Oriental.

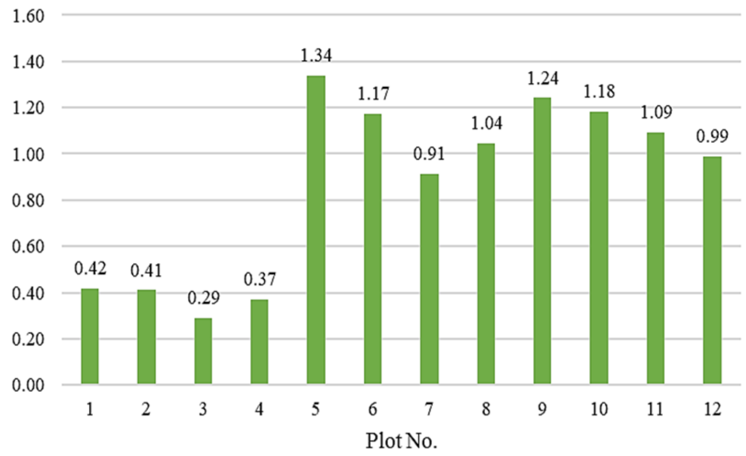

Fig. 6. Shannon-Weiner Diversity Index of mangroves and associates found in Mandangisiao Estuary, Jasaan, Misamis Oriental.

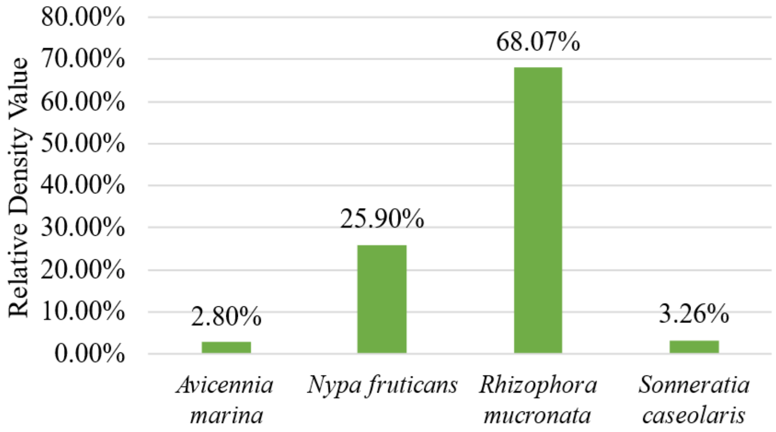

Fig. 7. Relative Density Index result of true mangrove species found in Mandangisiao Estuary, Jasaan, Misamis Oriental.

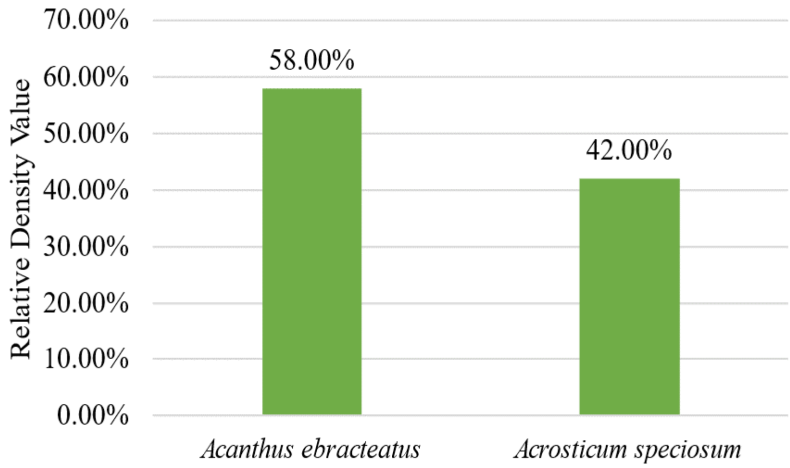

Fig. 8. Relative Density Index result of associated plants found in Mandangisiao Estuary, Jasaan, Misamis Oriental.

The species of mangroves namely *Rhizophora mucronata* and *Nypa fruticans*, were observed in all twelve plots, while *Avicennia marina* was recorded in plots 1, 6, 9, 10, 11, and 12. Furthermore, *Sonneratia caseolaris* was observed in plots 5, 6, 7, 8, 9, 11, and 12. For the associated plants, individual species of *Acanthus ebracteatus* were observed in plots 5, 6, 8, 10, 11, and 12. While the *Acrostichum speciosum* was observed in plots 5, 7, 9, and 10 (Fig. 4, Table 2).

Plots 5, 6, 9, 10, 11, and 12 have equally five species of mangroves and associates present, which consist of five different families and five genera. On the other hand, plots 2, 3, and 4 have the lowest number of different species observed, consisting of two families and two genera. While plots 7 and 8 have four species that can be found in each plot. Lastly, plot 1 has 3 species of mangroves and associated plants observed .

Mangroves and Associated Plants Diversity Indices

A. Mangrove and Associated Plants Diversity

The species diversity of mangroves in Mandangisiao Estuary, Jasaan has H' value of 0.87. Plots 9, 10, 11, and 12 (landward zone) has the highest average result of diversity index of 1.13, followed by plots 5, 6, 7, and 8 in the intermediate zone with 1.12 diversity index value; and lastly, plots 1, 2, 3, and 4 in the seaward zone evidently has the lowest average diversity value of 0.37 (Fig. 6). The result of this study shows that Mandangisiao Estuary in Jasaan has a relatively low species diversity.

This is due to low species richness and abundance of mangrove species. The dominance of few species is another factor affecting the diversity estimate of mangroves, notably the dominance of *Nypa fruticans* and *Rhizophora mucronata*, while other species are rare and few in number of individuals .

B. Mangrove Vegetation Structure

The community structure of mangroves has been measured using the relative values for density, frequency, and dominance. The Species Importance Value (SIV) for the entire sampling area was calculated using these values added together.

The species *Rhizophora mucronata* was noted to have the highest population density of 68.07%, which indicates that this species of mangrove has the highest count per unit area. This is followed by the species *Nypa fruticans* with 25.90%, *Sonneratia caseolaris* with 3.26%, and *Avicennia marina* with 2.80% (Fig. 7). The associated plants, *Acanthus ebracteatus* and *Acrostichum speciosum,* have 58.00% and 42.00%, respectively (Fig. 8). The species of *Rhizophora mucronata* are abundant in the seaward zone of the mangrove forest due to its massive stilt roots and adaptability to saline waters. Furthermore, its viviparity reproduction helps in the density of species in an area.

It has been discovered that the vegetation density reduces as one moves farther into the mangrove forest in the case of *Rhizophora mucronata* compared to other mangrove species (Ismail *et al.*, 2019).

The highest relative frequency is *Rhizophora mucronata* and *Nypa fruitcans* with 32.43%, followed by *Sonneratia caseolaris* with 18.92% and *Avicennia marina* with 16.22% (Fig. 9). The associated plants *Acanthus ebracteatus* has the highest relative frequency for the associated plants with 60.00% value, followed by the *Acrostichum speciosum* (40.00%) (Fig. 10). The high frequency of both *Rhizophora mucronata* and *Nypa fruticans* is due to their adaptability to saline waters and the dispersal of their saplings, that is also due to their mode of reproduction.

The species *Nypa fruticans* tops the relative dominance index result with 42.20%, followed by, *Rhizophora mucronata* with 25.73%, *Sonneratia caseolaris* with 22.94%, and lastly, *Avicennia marina* with 9.12%. (Fig. 11).

Conservation Status of Mangroves and Associated Plants

The assessment of conservation status showed that all species in the Mandangisiao Estuary are listed as Least Concern in the IUCN Red List. Nonetheless, the Mandangisao Estuary is currently experiencing human exploitation. Anthropogenic activities were observed in the area such as logging of *Rhizophora* trees, improper disposal of waste by the locals, building of houses in the nearby areas and the estuary become a docking site for fishing boats.

DISCUSSION

Mangrove forests are frequently zoned. Within the ecosystem, specific species inhabit niches that are only accessible to them. Other mangrove species are located farther inland, in estuaries affected by tidal action. Some mangrove species are found near shore, fringing islands, and sheltered bays (Mangrove Action Project, 2019).

As shown in Fig. 5, plots 1, 2, 3, and 4 were established in the tidal creek and more to the seaward side, and it was observed that *Rhizophora mucronata* mangroves dominated the area which may be explained by their physiological adaptations to saline conditions and are usually found growing in groups near or on the banks of tidal creeks. Stilted mangroves, like genus *Rhizophora*, can withstand a variety of intertidal environments, including salinity ranging from close to freshwater to fully concentrated seawater. They can withstand a variety of soil types, water patterns, and other

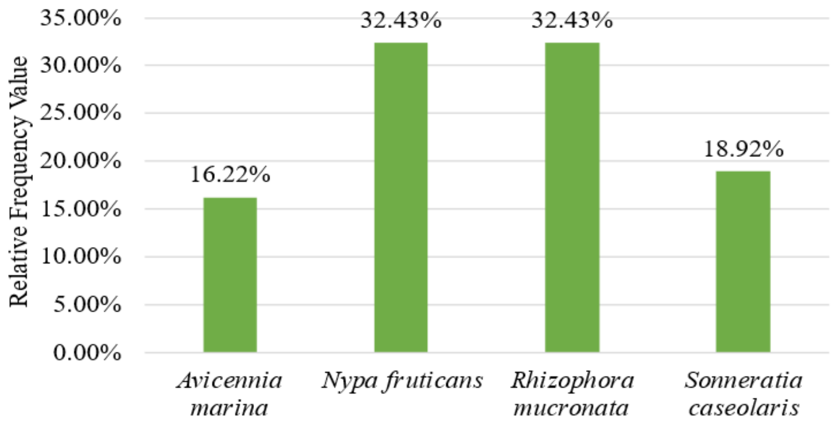

Fig. 9. Relative Frequency Index result of true mangroves species found in Mandangisiao Estuary, Jasaan, Misamis Oriental.

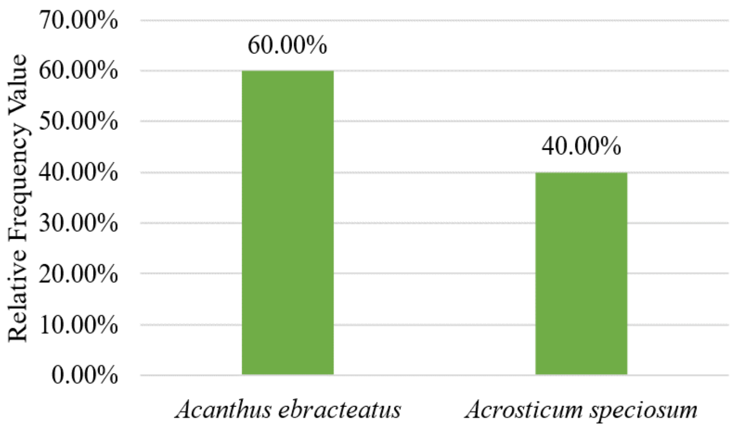

Fig. 10. Relative Frequency Index result of tassociated plants found in Mandangisiao Estuary, Jasaan, Misamis Oriental.

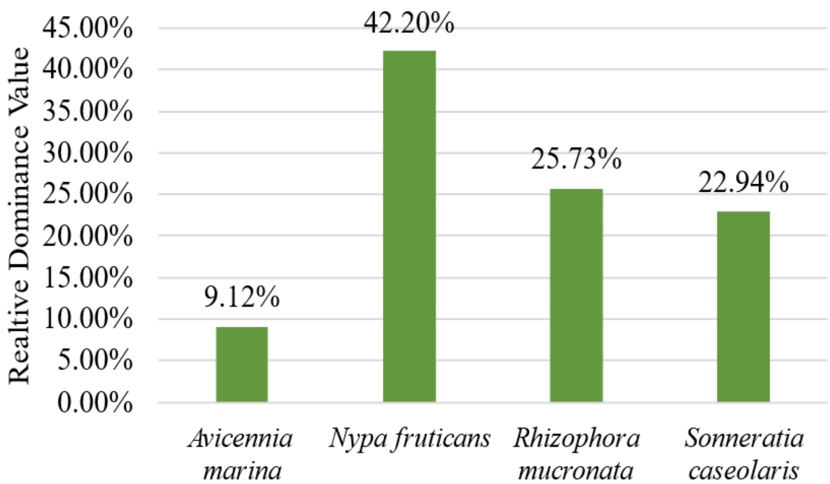

Fig. 11. Relative Dominance Index result of true mangrove species found in Mandangisiao Estuary, Jasaan, Misamis Oriental.

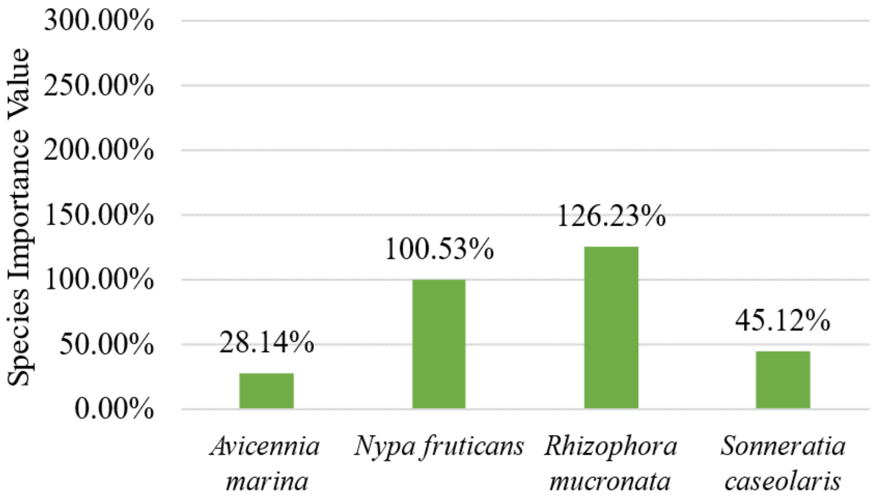

Fig. 12. Species Importance Value result of true mangrove species found in Mandangisiao Estuary, Jasaan, Misamis Oriental.

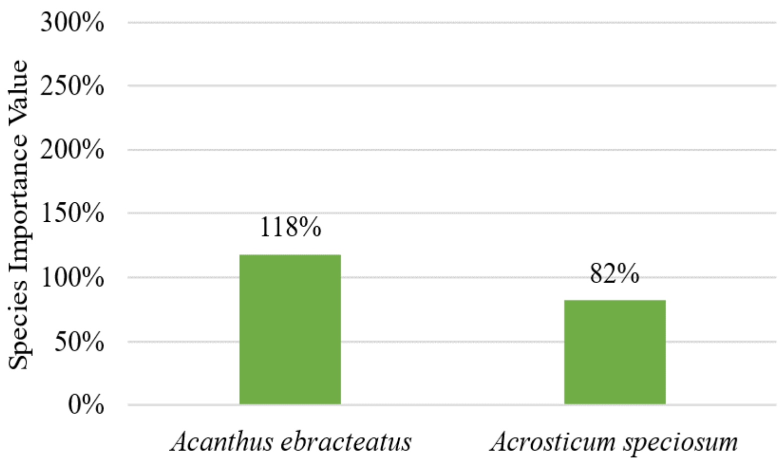

Fig. 13. Species Importance Value result of mangrove associates found in Mandangisiao Estuary, Jasaan, Misamis Oriental.

physical conditions. These mangroves are typically found in the middle of the intertidal zone, especially near the seaward edge of tropical mangrove stands (Duke, 2006). The mangroves and associated plants in the seaward zone also include the saplings of *Avicennia marina* and *Nypa fruticans*. The mangroves species *Avicennia marina* and associated plant *Nypa fruticans* were reported to be abundant in exposed shoreline locations as well as estuarine banks and have a robust tolerance for hypersaline conditions (Melana *et al.*, 2000).

The plots established in the intermediate zone of the mangrove forest (Fig. 5) harbors three species of true mangroves which includes the *Avicennia marina, Rhizophora mucronata,* and *Sonneratia caseolaris.* One of the native mangrove plants that can grow in mangrove forests on deeply muddy soil and tidal areas with mud banks is *Sonneratia caseolaris*, which is a member of the Lythraceae family. This tree has occasionally even been observed thriving in freshwater (Rahim & Bakar, 2018). The mangroves species in this area were associated by species *Acanthus ebracteatus* from Acanthaceae family and *Acrostichum speciosum* of family Pteridaceae in which few species can thrive well in coastal environments as it also tolerates salinity and waterlogging. The associated species differ according to geographic areas, latitude, soil types, estuarine upstream location, and tidal position (Duke, 2006).

In the transect near the landward zone (Fig. 5), *Nypa fruticans* dominated the area with the greatest number of individuals. Despite having the ability to grow in saltwater, their production increased in less salty environments, particularly those close to landward zones, with species showing different levels of water tolerance (Ball, 1998). It also includes the saplings and small trees of *Rhizophora* *mucronata* and *Avicennia marina* also a few tree species of *Sonneratia caseolaris* that were observed in each plot. The mangroves in this zone were also associated with species of *Acanthus ebracteatus* and *Acrostichum speciosum*. The growth and number of some associated plants increased in less saline environments as per observed in this study. Salty soils are not conducive to the growth of the majority of plants. Because salt reduces the rate and quantity of water that plant roots can absorb from the soil. Additionally, when present in high concentrations, some salts are poisonous to plants (Glenn *et al.*, 1999). Therefore, changes in coastal environments' salinity brought on by variations in precipitation, river flows, soil type, and evaporative demand are expected to have significant impacts on both the growth and species composition of mangroves and associates. Moreover, the geographic distribution of mangroves is mostly influenced by changes in sea level. Air temperature, salinity, ocean currents, storms, shore slope, and soil substrate are additional secondary influences. Mangroves can grow on sand, peat, and coral rock, but they typically developed on muddy soils (Bitantos *et al.*, 2017).

Species richness revealed a total of four true mangroves, and two associated plants. Evidently, the species richness of mangroves in Mandangisiao Estuary, Jasaan, is just half the number of mangroves recorded in the entire Municipality of Jasaan, with eight species of mangroves identified and other neighboring municipalities and city in Misamis Oriental (Mangroves in Macajalar Bay, 2019). However, the findings of this study are consistent with Bitantos *et al.* (2017) in which they also recorded four species of mangroves in Pamintayan, Damaquillas Bay, Zamboanga, Sibugay, Philippines. Moreover, mangrove forests frequently exhibit zonation, or spatial variation, both horizontally and vertically. Some species can be found in mosaics or in monospecific bands parallel to the shore; however, distribution patterns differ depending on the locality, both locally and regionally. Interspecific variation is also extremely considerable in the low species richness in each zone.

The diversity index result is attributed to a lack of species variation in the mangrove forest. Numerous studies have determined that mangrove forests have very low diversity indices compared to other tropical forest ecosystems because of their distinctive stand construction and their need for adaptability to harsh saline environments (Gevana & Pampolina, 2009). Furthermore, deforestation and other human activities alter the mangrove ecosystem, which causes several natural changes. This modification eventually leads to changes in species richness and composition. Presumably, among the four species of mangroves observed in the area, *Nypa fruticans* makes up the largest mangrove biomass and has a large basal area for the entire sampling area. This is due to the large number of individuals recorded for each species and the large area covered if combined. The density and girth of mangroves in an area are both factors that affect basal area. Smaller basal areas typically imply fewer trees, whereas larger basal areas suggest dense forests. A mangrove area could, however, be dense and still have a relatively small basal area because of the small tree diameter (Manual *et al.*, 2022).

Furthermore, among the four species of true mangroves and two species of associated plants documented, *Rhizophora mucronata* was noted to have the highest species importance value percen-tage of 126.23%, followed by *Nypa fruticans* (100.53%), *Sonneratia caseolaris* (71.99%), *Avicennia marina* (43.59%) (Fig. 12). Further, associated plants, *Acanthus ebracteatus* has the highest species importance value with 118%, followed by *Acrostichum speciosum* (82%) (Fig. 13). The result can be interpreted that *Rhizophora mucronata* had the most significant role in the mangrove ecosystem of the study site. A high species importance value index indicates the significant function and contribution that mangroves make to the wider ecosystem. Mangroves provide a significant supply of construction supplies, charcoal, and firewood for coastal populations (Nicolau *et al.*, 2017). Additionally, numerous organisms in this ecosystem, such as fish, shrimp, crabs, and mollusks, depend on mangrove waste for food and vegetation for shelter, foraging, and even spawning (Njana, 2020).

The expansion and concentration of the human population have a negative impact on mangrove forests. There will be increased anthropogenic effects on the forests as there are more people living in or close to mangroves (Alongi, 2002). Many mangrove habitats in big cities throughout the world have observed rapid loss and deterioration of forest cover (Branoff, 2017). Human activity had a significant impact on the structure of mangrove forests, but despite of this, people can work together to manage them (Walters *et al.*, 2008).

CONCLUSION

A total of four true mangrove species and two associated plants were recorded in Mandangisiao Estuary, Jasaan, Misamis Oriental under three families and three genera of mangroves and three families and three genera for the associated plants. The mangrove species that can be found in the Mandangisiao Estuary include *Avicennia marina, Nypa fruticans, Rhizophora mucronata*, and *Sonneratia caseolaris*. Associated plants comprise *Acanthus ebracteatus* and *Acrostichum speciosum*. Moreover, the diversity value of mangroves and associated plants in Mandangisiao

Estuary, Jasaan, Misamis Oriental is 0.87, which is considered to have a very low relative value. Moreover, for true mangroves *Rhizophora mucronata* had the highest relative density and species importance, while *Nypa fruticans* is the highest in terms of relative dominance. Both have the same highest value in relative frequency. All in all, the highest species importance value for true mangroves is *Rhizophora mucronata* with 126.23%. For associated plants, *Acanthus ebracteatus* has the highest values of relative density, relative frequency, and species importance. Mangrove vegetation varies in its adaptability depending on its zonation, versatility, or level of resistance. *Nypa fruticans* and *Rhizophora mucronata* species are more zonation-adaptive than other plant species, and they can be restored more rapidly. A conservation status assessment showed that all six species of mangroves and associated plants are of Least Concern according to the IUCN Red List. However, the adept dumping of garbage, frequent tree cutting, the docking of fishing boats, and the spread of human occupants were all possible dangers to the estuary's mangrove forest.

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THE LOCAL COMMUNITY UNDERSTANDING OF THE FACTORS INFLUENCING THE DECLINE OF SANINTEN (*CASTANOPSIS ARGENTEA* (BLUME) A.DC.) AND TUNGURUT (*CASTANOPSIS TUNGURRUT* (BLUME) A.DC.) IN THE BUFFER VILLAGES OF THE GUNUNG HALIMUN-SALAK NATIONAL PARK

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ABSTRACT
PENIDDA, E. I., JUMARI, BASKORO, K., SAHRONI, D., PENIWIDIYANTI, SUJARWO, W. 2024. The local community understanding of the factors influencing the decline of saninten (*Castanopsis argentea* (Blume) A.DC.) and tungurut (*Castanopsis tungurrut* (Blume) A.DC.) in the buffer villages of the Gunung Halimun Salak National Park. *Reinwardtia* 23(1): 15–32. — *Saninten* (*Castanopsis argentea*) and *tungurut* (*Castanopsis tungurrut*) are plant species belonging to the family Fagaceae, native to the mountainous forest ecosystem within the Gunung Halimun-Salak National Park (GHSNP). These species are currently classified as endangered according to the IUCN Red List due to their significance in providing seeds for consumption and wood for construction materials. This research aims to examine the local community's knowledge concerning the presence, scarcity, and underlying causes of the decline of both species in the buffer villages of GHSNP. In this study, we employed survey methods and semi-structured interviews conducted with various informants. The data collected were meticulously described and analyzed descriptively. The findings revealed that the local community, in general, holds knowledge about the scarcity of species primarily based on field observations rather than legal or conservation status. Currently, both species are challenging to locate in the buffer villages of the GHSNP. According to the local community's knowledge, the causes of species scarcity can be categorized into internal and external factors. Internal factors include both species having a slow natural regeneration pattern, difficulties in germination, and vulnerability of seedlings to environmental conditions. Meanwhile, external factors encompass seed and timber exploitation, habitat loss, climate changes, limited knowledge, skills, and understanding of forest plants, and the current perception among locals that *C. argentea* and *C. tungurrut* offer limited economic benefits, leading to the gradual neglect of these species' existence.

Key words: Conservation, edible fruit, ethnobotany, slow regeneration, threatened species.

ABSTRAK
PENIDDA, E. I., JUMARI, BASKORO, K., SAHRONI, D., PENIWIDIYANTI, SUJARWO, W. 2024. Pengetahuan masyarakat lokal mengenai penyebab kelangkaan saninten (*Castanopsis argentea* (Blume) A.DC.) dan tungurut (*Castanopsis tungurrut* (Blume) A.DC.) di desa penyangga Taman Nasional Gunung Halimun Salak. *Reinwardtia* 23

(1): 15–32. — Saninten (*Castanopsis argentea*) dan tungurut (*Castanopsis tungurrut*) merupakan jenis tumbuhan dari suku Fagaceae yang menjadi salah satu komposisi penyusun hutan pegunungan di Taman Nasional Gunung Halimun Salak (TNGHS). Kedua jenis ini kini termasuk ke dalam kategori tumbuhan terancam punah (*Endangered*) berdasarkan IUCN Redlist. Kedua jenis tersebut dimanfaatkan bijinya untuk dikonsumsi dan kayunya untuk bahan bangunan. Tujuan penelitian ini adalah untuk mengkaji pengetahuan masyarakat terkait keberadaan dan kelangkaan kedua jenis, serta penyebab kelangkaan kedua jenis di desa penyangga TNGHS. Penelitian ini dilakukan menggunakan metode survei dan wawancara semi terstruktur pada sejumlah informan. Data yang diperoleh diuraikan dan dianalisis secara deksriptif. Hasil studi mengungkapkan bahwa masyarakat lokal secara umum memiliki pengetahuan mengenai kelangkaan jenis berdasarkan fakta di lapangan, bukan berdasarkan undang-undang atau status konservasi, bahwa keberadaan kedua jenis tersebut saat ini sudah sulit ditemukan di desa penyangga TNGHS. Berdasarkan pengetahuan masyarakat lokal, penyebab kelangkaan jenis dapat dikelompokkan menjadi faktor internal dan faktor eksternal. Faktor internal diantaranya adalah kedua jenis memiliki pola regenerasi alami yang lama, sulit berkecambah hingga anakan yang rentan terhadap kondisi lingkungan. Faktor eksternal meliputi eksploitasi biji dan kayu, hilangnya habitat, adanya perubahan iklim, keterbatasan pengetahuan, keterampilan, dan pemahaman terhadap tumbuhan hutan, serta keberadaan saninten dan tungurut yang dinilai masyarakat kurang dapat memberikan manfaat ekonomi, sehingga menyebabkan eksistensi saninten dan tungurut mulai dilupakan.

Kata kunci: Buah konsumsi, etnobotani, jenis terancam, konservasi, regenerasi lambat.

INTRODUCTION

The Gunung Halimun-Salak National Park is one of the national parks established by Indonesia's Minister of Forestry Decree No. 175/Kpts-II/2003, aimed at conserving the conservation area (Kurniawan *et al*., 2018). This area boasts high biodiversity, particularly in plant species. According to the Gunung Halimun-Salak National Park Authority (2022), explorations conducted have documented over 700 species of flowering plants, comprising 391 genera from 119 families. *Castanopsis argentea* (*saninten*) and *C. tungurrut* (*tungurut*), commonly referred to as forest rambutans, are among the species that can be found in the Gunung Halimun-Salak National Park. The International Union for Conservation of Nature (IUCN) categorized *C. argentea* and C. *tungurrut* as endangered species in 2018 (Barstow & Kartawinata, 2018a; Barstow & Kartawinata, 2018b). It is no surprise that *C. argentea* is now a rare and protected species according to Indonesia's Minister of Environment and Forestry Regulation No. 106/2018, as this species has become increasingly challenging to find in Indonesia (Harapan *et al*., 2022). The knowledge held by communities living around forest areas becomes crucial information in determining subsequent solutions for sustainable biodiversity management.

Castanopsis argentea has experienced a 50% decline in population, while *C. tungurrut* has seen a 30% decrease in population over the last three generations. Within the conservation area of the Gunung Halimun-Salak National Park, *C. argentea* is scattered with populations ranging from seven to 13 trees per hectare, whereas *C. tungurrut* has a density of two to 35 trees per hectare (Barstow & Kartawinata, 2018a; Barstow & Kartawinata, 2018b). Research conducted by Bailey *et al*. (1995) as cited in Hidayat & Fijridiyanto (2002) observed a low presence of *C. argentea* saplings in the western part of the Gunung Halimun-Salak National Park. Additionally, Yumarni (2012) recommended the necessity for conservation efforts for both species within the Gunung Halimun-Salak National Park region.

Both species are extensively utilized by the local community surrounding the Gunung Halimun-Salak National Park. According to Rahayu & Harada (2004), the nearby communities utilize *C. argentea* and *C. tungurrut* as construction materials due to their high-quality wood. Wardah (2005) mentions that *C. argentea* fruits can be processed into flour used for making cakes. Research conducted by Hidayat & Fijridiyanto (2002) further suggests that there is an excessive use of *C. argentea* for natural medicinal purposes and its fruits can be consumed. The excessive exploitation of both species is suspected to be a reason contributing to their scarcity.

The management of endangered plant species often encounters various challenges, such as the lack of information regarding the causes of scarcity and extinction, as well as the absence of technical guidelines for effective planning (Primack, 1998). Exploitation of a species without considering conservation or sustainable management can lead to its endangerment and eventual extinction. Hence, exploring the knowledge of local communities, who coexist directly with *C. argentea* and *C. tungurrut*, becomes crucial in understanding the factors causing the scarcity of these species.

This research aims to assess the local community's knowledge regarding the presence and scarcity of *C. argentea* and *C. tungurrut*. Additionally, it seeks to understand the community's insights into the causes of scarcity for these species in the buffer villages surrounding Gunung Halimun-Salak

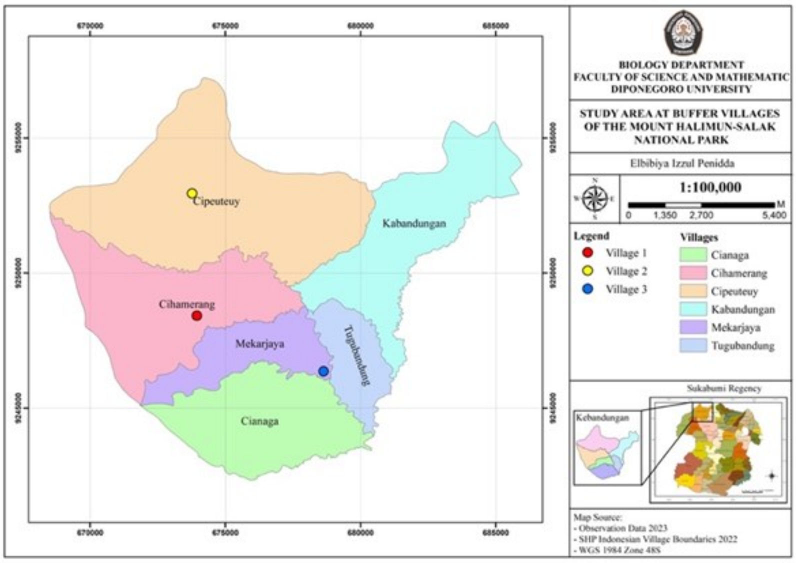

Fig. 1. Location of the study area in the buffer villages surrounding Gunung Halimun-Salak National Park.

National Park. Revealing the local knowledge from communities around the forest can serve as a reference and offer solutions to address issues related to scarcity, enabling the sustainable management of *C. argentea* and *C. tungurrut* to maintain their populations.

MATERIALS AND METHODS

Study Area

This research was conducted from December 2022 to March 2023 in the buffer zone of the Gunung Halimun-Salak National Park, which encompasses Cipeuteuy, Cihamerang, and Mekarjaya Villages within Kabandungan Sub-district, Sukabumi Regency, West Java (see Fig. 1). These villages were selected as research sites based on their proximity to the conservation area of the Gunung Halimun-Salak National Park and the local community's knowledge regarding the species and use of endangered plants, namely *Castanopsis argentea* (*saninten*) and *C. tungurrut* (*tungurut*).

Data Collection

Gentles *et al.* (2015) stated that the estimated number of informant to reach the saturated level in phenomological descriptive qualitative research is 12 participants. In this study, we employed survey methods and semi-structured interviews involving 22 informants knowledgeable about the causes of the scarcity of *C. argentea* and *C. tungurrut* species. The decision to limit the number of informants was based on the principle of data saturation, which occurs when no new information or themes emerge from additional interviews. In qualitative research, data saturation is an important criterion for determining sample size, as it indicates that we have obtained a sufficient depth and breadth of data to address the research questions. Additionally, this approach ensures that the research findings are based on a comprehensive understanding of the topic and are not influenced by potential bias or incomplete information. Our informants were directly engaged in utilizing both species in the buffer villages of Gunung Halimun-Salak National Park. Informants were purposefully selected based on recommendations from community leaders and individuals closely associated with both species. Additional informants were then identified using the snowball sampling method, relying on suggestions provided by already engaged informants within the researched villages. An overview of the specific questions can be seen in the Table 1.

Data Analysis

The data from informant interviews were analyzed descriptively (Tatlidil *et al*., 2009; Dawoe *et al*., 2012). Furthermore, the interview findings were quantified using a modified citation frequency (CF) presentation, adjusted to suit this research context. The employed formula is as follows:

$$CF = \frac{n}{N} \times 100\%$$

Here, "*n*" represents the quantity of information conveyed by informants, while "*N*" stands for the total number of informants. The percentage of

Table 1. Overview of the specific questions.

Data Type	No.	Aspects studied	Question overview
Respondent Characteristics	1	Name	What is your name?
	2	Age	How old are you?
	3	Gender	No need to ask.
	4	Education	What was the last education you received?
	5	Livelihood	What is your occupation?
Scarcity of *saninten* and *tungurut* species in the buffer villages of Gunung Halimun-Salak National Park	1	The existence of both species in the buffer villages of Gunung Halimun-Salak National Park	a. Do you know *saninten* and *tungurut*? b. How much do you know about these two species? c. Are you familiar enough with these two species? d. Are you aware of the existence of *saninten* and *tungurut*? e. Where are they distributed? f. Are their presence quite familiar around you?
	2	Community knowledge regarding the morphological differences between *saninten* and *tungurut*	a. Do you know the difference or could you differentiate between the two species? b. How do you differentiate the two species?
	3	Community knowledge about the rarity of both species	a. Do you know that these two species are protected and endangered plant species? b. How do you know that these two species are rare and protected? c. Has there ever been any outreach or counseling regarding endangered plant species in this area? d. Where does this socialization come from? e. When was the socialization held? f. Are you aware that there are sanctions for taking these species without permission? What is your response regarding this matter?
	4	Community knowledge regarding the causes of the scarcity of *saninten* and *tungurut*	a. What are the uses of these two species here? b. What are the majority used for? c. Which is more widely used, *saninten* or *tungurut*? d. Have you ever used these two species? e. Where did you get these species? From inside the forest or outside the conservation forest? f. What are these species used for? Selling or using them? Where are they sold? g. What is the reason behind selling these species?

information provided by respondents may exceed 100% as some individuals might share multiple crucial pieces of information. This variation in comprehension levels is due to differences in gender, age, education, and profession among the informants.

RESULTS

Community Knowledge of *Castanopsis argentea* and *C. tungurrut*

The ethnicity of the interviewed respondents was all Sundanese. The interviewed respondents were mostly male (81.82%) and were predomi-

Table 2. Local community knowledge regarding the morphological differences between *Castanopsis argentea* and *C. tungurrut.*

No.	Morphological characters	*Castanopsis argentea*	*Castanopsis tungurrut*
1	Tree canopy	Widened	Tall
2	Bark	Grayish brown	Greenish brown
3	Leaf	Smaller	Wider
4	Fruit's thorn	Shorter	Longer
5	Seed	Pyramid shape, in one fruit there are 3–5 seeds	Oval shape, in one fruit there is only one seed

nantly engaged in occupations, such as farming (54.55%) and construction work (13.64%). while female informants accounted for a lower percentage (18.18%) and were primarily involved in household activities (13.64%). In terms of age, over 50% of informants were aged over 56, followed by other productive age groups above 25. Regarding education, most informants had attended primary school (54.55%), with only 9.09% reaching a bachelor's degree level.

Castanopsis argentea and *C. tungurrut* trees have almost the same morphological characters. However, the locals in the study area (19 informants, 86%) can specifically differentiate the two species based on the morphological differences. The morphological differences between the two species are tabulated in Table 2 and shown in Fig. 2. Based on the knowledge of the local community, both species have several characteristics that can be simply differentiated. What can be seen clearly is that the canopy of *C. argentea* tree is wider than *C. tungurrut*. The tree of *C. argentea* has many branches and twigs, while *C. tungurrut* has a taller tree canopy and fewer branches and twigs. The trunks of *C. argentea* and *C. tungurrut* trees can be differentiated by the color of their bark, where the trunk of *C. argentea* is grayish brown bark, while *C. tungurrut* is brown, tending to greenish bark.

The leaves of the two species differ in leaf size. *Castanopsis argentea* leaves are smaller than *C. tungurrut*. The fruits of *C. argentea* and *C. tungurrut* can be distinguished by their spines, where the spines on the skin of *C. argentea* fruit are shorter compared to *C. tungurrut*, which are longer. In one *C. argentea* fruit there are 3–5 seeds which are slightly round and triangular (pyramid) and are smaller in size than *C. tungurrut*. In *C. tungurrut* fruit, there is only one seed, which is oval and larger in size than the seeds of *C. argentea*. The difference is that *C. argentea* cupule does not have branched spines and there are 3–5 seeds in one cupule, while *C. tungurrut* has one seed per cupule and the spines are slender and branched. The seeds of *C. argentea* can be eaten raw and have a sweeter taste, while *C. tungurrut* seeds must be cooked first before consumed and have a slightly bitter taste.

The analysis of the presence and scarcity of *C. argentea* and *C. tungurrut* in the buffer villages surrounding the Gunung Halimun-Salak National Park (see Table 3) indicates that a majority of the community members have a connection to these species through their forest activities and previous and current consumption of their fruits. Apart from using the fruits as snacks, the community also identifies these species through their wood usage. Additionally, people generally differentiate between *C. argentea* and *C. tungurrut* based on leaf size and fruit taste.

The community's knowledge of the presence and habitat of *C. argentea* and *C. tungurrut* generally indicates that both species are commonly found in the forest, although some have also encountered these endangered species growing around the village. The populations of *C. argentea* and *C. tungurrut* are relatively balanced. In addition, some informants believe that the populations of *C. argentea* and *C. tungurrut* in the forest have become more abundant than before due to the community's prohibition of logging wood from the forest. The community's response to the scarcity of these two species suggests the necessity for protective measures and refraining from harvesting them in their natural habitat.

Causes of Scarcity and Conservation Efforts

The scarcity of *C. argentea* and *C. tungurrut*, as revealed by the data, is primarily due to the utilization of their wood for construction purpo-ses and their fruits for consumption (see Table 4). The scarcity of these species is influenced by several factors, including challenges in germination (31.82%), infrequent fruiting periods (27.27%), and land use changes (22.73%). The involvement of local communities in forest areas has led to a decline in the populations of these species throughwood harvesting (45.45%) and the utiliza-

Table 3. Presence and scarcity of *Castanopsis argentea* and *C. tungurrut* in buffer villages of the Gunung Halimun-Salak National Park.

No.	Parameters	No.	Informants' Responses (%)	
1	Engagement with the species	1	Entering and exiting the forest	59.09
		2	Consuming the seeds	50.00
		3	Participating in species propagation	13.64
		4	Using plant parts for roofing or crafts	9.09
		5	Participating in reforestation or tree planting initiatives within the Gunung Halimun-Salak National Park	9.09
		6	Previously worked as a conservation area manager	9.09
		7	Participating in awareness programs	4.55
		8	No association	4.55
2	Community's knowledge of the species	1	Knows and consumes the seeds	68.18
		2	Does not know	18.18
		3	Knows and plants them beside the house	4.55
		4	Knows and utilizes their woods	4.55
		5	Knows but does not utilize them	4.55
3	Community's knowledge of species' differences	1	Can distinguish	81.82
		2	Does not know	18.18
4	Community's knowledge of species' presence	1	Knows; in the forest	36.36
		2	Knows; in the forest, but previously found in the village	36.36
		3	Does not know	22.73
		4	Knows; in the forest and around the house	4.55
5	Community's knowledge of species' population	1	*Castanopsis argentea* and *C. tungurrut* are equally abundant	45.45
		2	*Castanopsis argentea* and *C. tungurrut* are equally abundant, and now are more abundant than before	27.27
		3	Does not know	22.73
		4	*Castanopsis argentea* and *C. tungurrut* are equally abundant, but previously more abundant than now	4.55
6	Community's knowledge of species' scarcity	1	All plant species in the forest cannot be harvested, except for their fruits	45.45
		2	Does not know	22.73
		3	*Castanopsis argentea* and *C. tungurrut* cannot be harvested.	31.82
7	Community's response to species' scarcity	1	Does not know	54.55
		2	Should be protected	22.73
		3	Does not need to be harvested	22.73

Fig. 2. Morphological comparison between *Castanopsis argentea* and *C. tungurrut*. A. Bark of *C. argentea.* B. Bark of *C. tungurrut*. C. Fruit of *C. argentea.* D. Fruit of *C. tungurrut*. E. Seeds of *C. argentea.* F. Leaves of *C. argentea.* G. Seeds of *C. tungurrut*. H. Leaves of *C. tungurrut.* Photos by Peniwidiyanti (A-D, F & H) and Deni Sahroni (E & G).

Table 4. Causes of species scarcity.

No	Parameters	No.	Informants' Responses (%)	
1	Species utilization	1	Uses the wood for construction purposes	86.36
		2	Consumes the fruit	86.36
		3	Does not know	13.64
2	The community's knowledge regarding species scarcity causes	1	Difficulties in germination	31.82
		2	Infrequent fruiting periods	27.27
		3	Land use changes	22.73
		4	Wood harvesting	18.18
		5	Does not know	18.18
		6	Slow plant growth	13.64
		7	Seeds consumed by humans and animals	13.64
		8	Other growth disturbances	4.55
3	The community's role in species scarcity causes	1	Wood harvesting	45.45
		2	Seeds utilized by humans	31.82
		3	Does not know	9.09
		4	Slow growth	9.09
		5	Land use changes	4.55

tion of fruits and seeds (31.82%).

Castanopsis argentea and *C. tungurrut* are recognized for their wood, which serves as a construction material for houses. In fact, within the researched areas, several houses still utilize the wood from both species (see Fig. 3). These woods have a prolonged utility due to their classification as durable and of commendable strength. Generally, the local community in the buffer villages surrounding Gunung Halimun-Salak National Park uses *C. argentea* and *C. tungurrut* wood to support roof structures, such as roof trusses. Additionally, both types of wood are employed as door and window frames, as well as for house ceilings.

Gunung Halimun-Salak National Park has a long history of changing the area's status. Before Indonesia got its independence in 1945, the Dutch initially designated the area as a nature reserve. However, in 1961, it was altered and managed by the *Perusahaan Umum Kehutanan Negara* (Indonesia state-owned enterprise or Perum Perhutani) to harvest the woods. Then, in 1992, the Mount Halimun landscape was designated as Halimun National Park. The area of the national park changed again in 2003, when part of the Mount Salak landscape, which was managed by Perum Perhutani, was then included as part of the Gunung Halimun-Salak National Park area. The local people living in the buffer villages used to have access to harvest *C. argentea* and *C. tungurrut* woods. However, since 2016, they are no longer doing wood harvesting, because the entire area has become part of the national park with strict regulations.

The local community recognizes that *C. argentea* and *C. tungurrut* possess quality attributes due to their strong, water-resistant, and termite-resistant wood properties. Between 1980 and 1999, these woods were among the preferred choices, although their wood mass was heavy and challenging to transport from the forest. In the past, locals would generally obtain *C. argentea* and *C. tungurrut* woods for personal needs, while some would engage in selling them. The trade of these wood species within the buffer villages of the Gunung Halimun-Salak National Park involves consumers ordering wood from skilled wood workers familiar with navigating the forest. Wood sellers would then locate and fell *C. argentea* or *C. tungurrut* trees, processing them for immediate use in building houses or crafting tools based on the customers' requests.

One informant from Cipeuteuy Village used *C. argentea* wood to complete the ceiling, rafters, and frames in their house. This *C. argentea* wood was acquired by ordering it from a carpenter willing to retrieve it from the forest. The house, established in 1987, reached 35 years old in 2022. Despite its age, the building remains sturdy, show ing no signs of decay or termite damage. Interestingly, even the house's rafters were made solelyof *C. argentea* wood without the use of iron. The *C. argentea* wood used in construction can be seen in Fig. 3. In 1987, *C. argentea* wood was

Fig. 3. The utilization of *C. argentea* and *C. tungurrut* wood. A & B. *Castanopsis argentea* wood is used for house ceilings. C. *Castanopsis argentea* wood for window frames. D. *Castanopsis argentea* wood for casings. E & F. *Castanopsis tungurrut* wood is used for roof rafters. Photos by Elbibiya Izzul Penidda.

Fig. 4. The expansion of intercropping (*tumpangsari*) farming areas in Cipeuteuy Village. Photo by Deni Sahroni.

Table 5. Local community's methods of propagation.

No.	Parameters	No.	Informants' Responses (%)	
1	Implementation of propagation techniques for the *C. argentea* and *C. tungurrut* species by the community	1	None yet	63.64
		2	Does not know	18.18
		3	Exists; natural propagation	9.09
		4	Exists; seed propagation	4.55
		5	Exists; cutting propagation but has not been successful	4.55
2	Local propagation techniques for other species	1	Does not know	63.64
		2	Propagation via seeds	27.27
		3	Natural propagation	9.09
3	Challenges encountered in local species conservation efforts	1	Does not know	72.73
		2	No initiative yet	13.64
		3	Plants easily perish	13.64

relatively expensive at 18,000.00 IDR per m^3 from the initial seller. Therefore, the use of *C. argentea* or *C. tungurrut* wood as construction materials was limited, considering the economic capabilities at that time.

Another informant from Mekarjaya Village also utilized *C. argentea* wood for crafting roof trusses and casings (ceiling supports) for their house starting in 2012. By 2022, this construction wood had aged around 10 years (see Fig. 3). Unlike the previous informant, the *C. argentea* wood used by the Mekarjaya Village informants did not come from the forest; instead, it was sourced from *C. argentea* trees planted near their house. Planting *C. argentea* trees and later harvesting them after 25 years of growth is one approach the community adopts to utilize *C. argentea* wood without having to venture into the forest. This stems from the aspiration to construct homes using high-quality wood. During the 1980s, *C. argentea* wood was esteemed as the top-quality construction timber, commanding a relatively high market price. This made it more accessible for individuals with limited economic means to plant and later harvest the wood themselves. Alongside the use of *C. argentea* wood, the community in the buffer villages of Gunung Halimun-Salak National Park also utilized *C. tungurrut* wood. An informant from Cihamerang Village employed *C. tungurrut* wood as the roofing material for their house. Obtained from the forest around 20 years ago by felling a roughly 30-year old *C. tungurrut* tree, this wood was used for the house's rafters (see Fig. 3). Despite displaying minor decay along the edges caused by termite bites, the *C. tungurrut* wood has endured and remains robust and resilient. With the expansion of the Gunung Halimun-Salak National Park's working area in 2003, there has been no extraction of *C. argentea* or *C. tungurrut* wood from the forest area. This is due to regulations that prohibit individuals or community groups from harvesting wood in the forest. However, at the start of the transition phase when the entire operational area previously managed by the state-owned timber company (*i.e.* Perum Perhutani) transformed into a conservation zone, the Gunung Halimun-Salak National Park Authority still allowed local communities in the buffer villages to harvest one tree from the forest for personal use, prohibiting its sale. Additionally, the extraction of trees with small trunk diameters was forbidden to prevent a decline in the species population. Since 2011, the logging of trees for construction timber within the Gunung Halimun-Salak National Park has decreased compared to previous years due to the implementation of penalties and limitations on access to the conservation area.

The harvesting of *C. argentea* and *C. tungurrut* wood ceased in the early 2000s. However, locals still utilize the seeds of these species for consumption. *Castanopsis argentea* and *C. tungurrut* bloom and bear fruit once a year, typically during a prolonged dry season. When these species bear fruits, communities in the buffer villages of the Gunung Halimun-Salak National Park gather them, whether they have fallen to the forest floor or remain on the trees. Usually, locals collect *C. argentea* or *C. tungurrut* fruits for personal use. Additionally, one informant mentioned it is common for people to bring sacks and fill them with these fruits. The extensive fruit collection significantly reduces the chances of new *C. argentea* or *C. tungurrut* saplings growing, posing a severe threat to their natural population in the forest.

Given the substantial exploitation of *C. argentea* seeds, propagation efforts become crucial as a conservation measure. Seeds that can be germinated must be ripe, as indicated by the fruits falling from the trees by themself with opening cracking peel. The community was still collecting *C. argentea* seeds to consume (see Table 3 and Table 4). Because the tree does not bear fruit every year. The seeds taste delicious, and the locals consider this quite special. Apart from that, in the past, the populations of *C. argentea* and *C. tungurrut* were abundant. However, based on current locals' perceptions, it is more abundant than before (see Table 3), so people do not worry about the regeneration of both species.

Land use conversion is one of the reasons for the scarcity of *C. argentea* and *C. tungurrut* species (see Table 3). When the forest corridor managed by Perum Perhutani shifted into a production forest, the management introduced a system of "*tumpangsari*" (intercropping). In 2003, the forest management responsibility was transferred to the Gunung Halimun-Salak National Park Authority. Following Indonesia's Minister of Forestry Regulation No. P.56/2006 regarding National Park Zoning, which served as the basis for establishing a specific zone, the area's utilization to support thelivelihoods of local communities (before its official recognition as a national park). Due to the high demand from local communities to establish new "*tumpangsari*" farming plots for their livelihoods, the Gunung Halimun-Salak National Park Authority has opened new "*tumpangsari*" fields. However, the area surrounding the forest corridor is the native habitat of *C. argentea* and *C. tungurrut* (see Fig. 4). Additionally, some community groups have illegally expanded "*tumpangsa ri*" areas.

Due to the opening of intercropping(*tumpangsari*) areas around the forest corridor, the Gunung Halimun-Salak National Park Authority, together with the forest buffer zone communities, signed a cooperation agreement to manage thefor-est corridor. One of the agreements stated that areas implementing the "*tumpangsari*" system must be planted with native plants from the Gunung Halimun-Salak National Park. However, despite this,communities in the buffer zones of Gunung Halimun-Salak National Park continue to cultivate their land. The Gunung Halimun-Salak National Park Authority encourages these communities to also plant native species on their agricultural land. The commonly planted native tree species by communities are *rasamala* (*Liquidambar excelsa* (Noronha) Oken) and *puspa* (*Schima wallichii* (DC.) Korth.). These two plant species are highly sought after by the community due to their valuable wood and relatively rapid growth. Consequently, few, if any, farmers are cultivating *C. argentea* and *C. tungurrut* in their fields, despite these plants being native and currently facing extinction.

Informants from Cipeuteuy and Mekarjaya Villages reported that 10 to 20 years ago, *C. argentea* and *C. tungurrut* thrived in the forest corridor area. However, with the opening of new fields and given the slow growth and extensive regeneration period of these species, as they mature and their canopy spreads, shading the crops below, the community is compelled to cut them down and replace them with other tree species that offer greater economic benefits.

Based on interviews with the informants, the propagation methods for *C. argentea* and *C. tungurrut* are still unknown to many people (63.64%), despite some starting to use methods like natural propagation, seeds, and cuttings (see Table 5). Harvesting wood and seeds and a lack of knowledge about the growth of these two endangered species have become serious problems for current propagation and cultivation efforts. Moreover, conservation efforts for *C. argentea* and *C. tungurrut* face obstacles due to community unawareness about available actions (72.73%), a lack of initiative to start conservation activities (13.64%), and a perception that these species are prone to easy mortality (13.64%).

DISCUSSION

Local Community Knowledge of *Castanopsis argentea* and *C. tungurrut* Population Status

The residents living around the villages adjacent to Gunung Halimun-Salak National Park generally understand *C. argentea* and *C. tungurrut* plants. Furthermore, some informants can explain the morphological differences between these two endangered plant species. Based on Murna *et al.* (2020), the canopy type on the wide and round *C. argentea* tree can be interpreted as globular, while the canopy type on the tall and slender *C. tungurrut* is called columnar. Heriyanto *et al.* (2007) stated that the wood of *C. argentea* tree is gray-brown to pink, the sapwood or middle wood is white, light yellow and sometimes reddish. In contrast, according to Putri & Suhendri (2018), the wood of *C. tungurrut* is covered with greenish bark. Other differences between *C. argentea* and *C. tungurrut* can be seen in the leaves and cupules. Heriyanto *et al.* (2007) stated that *C. argentea* has elongated pointed leaves (lanceolate), measuring 7–12 cm, 2–3.5 cm wide, 5–6 cm thick. Based on Harapan *et al.* (2022), *C. argentea* has leaves that are shiny on the top and have a slightly silvery colour on the bottom, while based on Barstow & Kartawinata (2018), *C. tungurrut* has leaves with golden brown hair when young, the surface of the leaves is colored dark green on top and brownish on the bottom when old. Harapan *et al.* (2022) informed that *C. argentea* and *C. tungurrut* have similar sharp spiny cupules.

Knowledge regarding the existence of both species is widespread among individuals in the late

Table 6. Factors contributing to the scarcity of *Castanopsis argentea* and *Castanopsis tungurrut*

No.	Internal Factors	No.	External Factors
1.	A slow natural regeneration pattern	1.	Excessive exploitation of seeds
2.	Difficulties in germination	2.	Timber exploitation in the past
3.	Vulnerability of saplings of both species to environmental conditions	3.	Habitat loss due to land use changes leading to their diminishing presence
		4.	Climate change
		5.	Limited knowledge, skills, and understanding of forest plants

adult age category (36–45 years old) up to the elderly (65 years and above). Their past and current activities involving forest expeditions and consumption of *C. argentea* and *C. tungurrut* seeds have made them easier to distinguish between the two. Additionally, informants who have attempted to propagate mountainous plant species or have been involved in conservation management also possess knowledge about *C. argentea* and *C. tungurrut* trees.

Among the younger generation in the study area, only a few informants in the late adolescent (17–25 years old) and early adulthood (36–45 years old) categories are familiar with both species. The prohibition of activities or resource extraction from the forest is a significant factor contributing to the current generation's limited knowledge of *C. argentea* and *C. tungurrut*. Moreover, the populations of these species are now scarce in the vicinity of the villages. As a result, their understanding of *C. argentea* and *C. tungurrut* is mainly derived from stories passed down by elders or occasional educational sessions conducted by the Gunung Halimun-Salak National Park Authority. Another reason why the younger generation is less acquainted with *C. argentea* and *C. tungurrut* is the shift in social behavior due to technological advancements. The rise in technology can be observed through the increased engagement of the community in television programs and the widespread use of gadgets. Suryono (2019) explains that changes in social behavior can result from external factors, such as innovations in technology. The younger generation, who have never entered the national park area, certainly do not have sufficient knowledge to recognize and differentiate between *C. argentea* and *C. tungurrut*. The reduced interest and attention of the younger generation towards both species needs a serious concern because this does not only happen around the Gunung Halimun-Salak National Park but also in many other areas, such as community groups in Gayo Highland (Navia *et al.,* 2020), the Minangkabau and the Mandailing ethnic groups (Pawera *et al.,* 2020), and Batak Karo ethnic group (Lavenia & Dewi, 2020), due to limited access and opportunities for the younger generation to further explore forests and the current convenience of foods, so they do not need to enter the forests to collect food sources.

The utilization of *C. argentea* and *C. tungurrut* seeds by the local community has been known for ages, although most informants nowadays find consuming both seeds challenging. The seeds of *C. argentea* boast a sweeter and softer taste compared to *C. tungurrut*. They can be consumed directly or processed beforehand. In the past, certain community groups even used *C. argentea* seeds to produce flour. This aligns with research conducted by Wardah (2005), which mentions that *C. argentea* seeds can be processed into flour for making cakes. Apart from being used as a raw material for processed foods, consuming *C. argentea* seeds is believed to help maintain bodily health and is used as a natural remedy (Hidayat & Fijridiyanti, 2002). In contrast to *C. argentea* seeds, *C. tungurrut* seeds require various processing methods like boiling, grilling, frying, or roasting before consumption. Additionally, *C. tungurrut* seeds have a slightly bitter taste. Harada (2004) highlighted the utilization of *C. argentea* and *C. tungurrut* by communities surrounding the Gunung Halimun-Salak National Park, not only as food and construction materials for homes but also as fuel sources, such as firewood to cook traditionally. Even today, residents near Cikaniki—a research station managed by the Gunung Halimun-Salak National Park Authority—occasionally indulge in *C. argentea* and *C. tungurrut* seeds as snacks during their fruiting seasons (Dewi *et al.*, 2023), despite *Castanopsis* spp. having a notably low regeneration rate (Nurdiana & Buot, 2021).

Generally, the community is aware that *C. argentea* and *C. tungurrut* can be found growing within the forest area. In fact, after several years of restrictions on resource extraction from the forest, they understand that the populations of *C. argentea* and *C. tungurrut* should be more plentiful now. The community's awareness of refraining from taking wood from the forest has developed due to regular socialization activities held every year. Tinambunan (2011) explains that the Gunung Halimun-Salak National Park Authority communicates the regulations enforced among the community. These regulations include prohibitions, such as entering areas designated as nature reserves (1953–1992), logging within the Gunung Halimun-Salak National Park zone, land cultivation, and selling forest products. However, the interview results in this study indicate that, specifically, the community lacks knowledge about the specific protected plant species, their conservation status, and the penalties for violating these regulations. The community generally perceives that all plant species within the forest area are protected and should not be harvested. Moreover, concerning the community's response to the scarcity of *C. argentea* and *C. tungurrut*, only a few are aware of potential actions to take, while others believe that plants within the forest area should be conserved and left undisturbed.

The Threat of Extinction to *Castanopsis argentea* and *C. tungurrut*

Castanopsis argentea and *C. tungurrut*, both belonging to the family Fagaceae, are plant species that dominate mountainous forests. The silvicultural lifespan of these species is relatively long; *C. argentea* can live up to 75 years (Barstow & Kartawinata, 2018a), while *C. tungurrut* can survive for up to 100 years (Barstow & Kartawinata, 2018b). They are primarily used for construction timber, and their seeds are consumed by both humans and animals. The community's awareness of the scarcity of these species in the buffer villages of Gunung Halimun-Salak National Park can be divided into two factors: internal and external (see Table 6). Internal factors originate from the physiology and environmental conditions in which these species grow, while external factors are human-induced causes contributing to their scarcity.

Internal Factors

1. A Slow Natural Regeneration Pattern

The communities in the buffer villages of the Gunung Halimun-Salak National Park previously utilized *C. argentea* and *C. tungurrut* wood for house construction, which could be harvested around 20 to 35 years of age. This suggests that both species have a long lifespan. Typically, *C. argentea* and *C. tungurrut* only bear fruit once a year, following a prolonged dry season. The fruits produced annually often contain seeds that are not always viable, as commonly found seeds tend to rot or be empty. *Castanopsis argentea* sometimes flowers from August to October, followed by fruiting from November to February. However, locating natural saplings of these tree species is challenging as fallen fruits easily decay or get damaged due to consumption by animals or humans (Heriyanto *et al*., 2007). *Castanopsis argentea* exhibits a clustered distribution pattern and a low regeneration capacity, although its vertical density typically demonstrates an inverted J-curve in the forested areas of the Gunung Gede Pangrango National Park (Hilwan & Irfani, 2018). On the other hand, regarding the *C. tungurrut* species, Simbolon (2001) elaborates that the regeneration of *C. tungurrut* in the submontane forests of Mount Halimun is notably poor and experiences a high mortality rate.

2. Difficulties in Germination

More than 30% of the respondents indicated that the scarcity of *C. argentea* and *C. tungurrut* is due to difficulties in germination. This is supported by various research endeavors aimed at propagating these endangered species. *Castanopsis argentea* propagation has been experimented with using in vitro methods due to the challenges of propagating the species from seeds (Surya *et al*., 2017). In addition, the methodology for propagating *C. tungurrut* is currently unknown.

3. Vulnerability of C. argentea and C. tungurrut Saplings to Environmental Conditions

Another challenge in increasing the population of *C. argentea* and *C. tungurrut* is the threat of seedling damage due to their surrounding habitat. Disruptions and potential damage to *C. argentea* seedlings can result from drought, being shaded, or competing with other plants. The presence of wildlife also poses a threat to the growth of both *C. argentea* and *C. tungurrut* seedlings, such as wild boars. Typically, seedling trees lack sufficient woody structure, thus lacking the resilience necessary for their survival (Raharjo *et al*., 2017). Survival rate tests of *C. argentea* and *C. tungurrut* seedlings in restoration areas indicated a low percentage, with 66.67% for *C. argentea* and 33.33% for *C. tungurrut*, primarily due to stem breakage or disruptions caused by weeds (Handayani *et al*., 2019).

External Factors

1. Excessive Exploitation of Seeds

Castanopsis argentea and *C. tungurrut* are two plant species classified as endangered, yet Indonesia's Minister of Environment and Forestry Regulation No. 106/2018 only designates *Castanopsis argentea* (*saninten*) as a protected plant species in Indonesia. Additionally, Minister of Environment and Forestry Regulation No. 35/2007 regarding Non-Timber Forest Products specifies that *Cas-*

tanopsis spp. species can only utilize the bark, as it can be processed into natural dye. This demonstrates the government's commitment to reducing potential disturbances and the extinction of *Castanopsis* species in Indonesia. Therefore, excessive collection of fruits and seeds from *C. argentea* or *C. tungurrut* should be avoided, except when the trees of these species are outside conservation areas and are specifically cultivated for fruit, seed, or timber utilization. The past excessive utilization of fruits and seeds by the community has undoubtedly contributed to the decline in the population of both *C. argentea* and *C. tungurrut* seedlings and trees today.

2. Timber Exploitation in the Past

The challenge akin to the utilization of fruits and seeds involved the overharvesting of *C. argentea* and *C. tungurrut* wood, leading to a significant decline in their populations. Between 1978 and 2003, before the expansion of the Gunung Halimun-Salak National Park into the surrounding villages, such as Cihamerang, Cipeuteuy, and Mekarjaya, the forest corridor within these villages was managed as a production forest by Perum Perhutani (State-owned enterprises of Indonesia). In 2016, the entire area, which was managed by Perum Perhutani, became part of the Gunung Halimun-Salak National Park area (BTNGHS, 2022). An informant mentioned that during this period, the state-owned timber company (*i.e.* Perum Perhutani) extensively harvested fully grown trees in the forest corridor, including the species of *C. argentea* and *C. tungurrut*. In addition to being excessively harvested by timber company, the logging of *C. argentea* and *C. tungurrut* wood in the past was also carried out by communities for various purposes, such as house construction, bridge building, and firewood. *Castanopsis argentea wood* is classified under durability class III, and strength class II (KemenPUPR 1977), while *C. tungurrut* wood falls within durability class III-IV, and strength class I-II (Krisdianto, 2007). The exploitation of *C. argentea* and *C. tungurrut* wood was a significant factor contributing to the scarcity of these species. This assertion is supported by Barstow & Kartawinata (2018a, 2018b), who stated that the populations of both species in Java Island have drastically decreased, likely due to their utilization as construction timber and their excessive exploitation.

3. Habitat Loss Due to Land Use Changes Leading to Their Diminishing Presence

The conversion of land use poses a threat to the habitats and populations of *C. argentea* and *C. tungurrut* in the Gunung Halimun-Salak National Park. Tinambunan (2011) stated that communities are not allowed to cultivate production forest land after the conversion of production forests by Perum Perhutani. Although, Gunung Halimun-Salak National Park Authority designating the zones surrounding the forest corridor as "*tumpangsari*" forests (Supriyanto *et al.*, 2010). So that, opening up fields and employing mixed land use around the forest corridors inevitably diminish and harm the habitat conditions for these species. While 10–20 years ago, *C. argentea* and *C. tungurrut* were commonly found around villages and forest corridors, the increasing shift in land use and the high economic needs of the communities have gradually displaced these two endangered plant species. They have been substituted by other tree species that grow faster and can be cultivated in their agricultural areas. Knowledge about *C. argentea* and *C. tungurrut* has also dwindled from generation to generation due to the difficulty in encountering and utilizing these endangered trees in village areas. Additionally, the community has not fully adhered to the conservation area management's advice to plant native trees within the Gunung Halimun-Salak National Park (Tinambunan, 2011).

4. Climate Change

Information gathered from interviews indicates that over the past five years (2018–2022), both *C. argentea* and *C. tungurrut* trees within the forest area of the Gunung Halimun-Salak National Park have not produced flowers or fruits. Kurni (2024, personal communication) said that there is absence of fruiting observed for both species for nearly 5–6 years in the Cibodas Botanical Gardens.. This situation is likely due to Indonesia's general experience of La Niña, which prolonged the rainy season beyond its usual duration. The La Niña event from 2020–2022 caused an unusual rainfall anomaly, extending its impact not only in Indonesia but also across the Pacific region (Hasan *et al.*, 2022; Gao *et al.*, 2022). The La Niña phenomenon leads to increased rainfall, which can hinder the flowering process. When there is high rainfall and sufficient nutrients, plants may prioritize shoot growth, leading to increased levels of GA and endogenous auxin, affecting the initiation of flowering (Sarvina & Sari, 2017). Climate change, causing weather instability in a region, results in changes in temperature and other environmental conditions. This can potentially influence the flowering induction process and photoperiod for each plant. Prolonged periods of high rainfall and lower temperatures than usual can be factors contributing to the lack of flowering and fruiting in both *C. argentea* and *C. tungurrut*. Boudreau (2008) cited in Hamzah (2010) states that cold nighttime temperatures hinder or delay flowering in certain plants. Hamzah (2010) mentions that the altitude above sea level also affects plant flowering, with plants grown at lower altitudes flowering earlier than those planted at higher elevations. Excessive rainfall is linked to prolonged sunlight exposure, which has an impact on the gene that regulates flowering, called the *CONSTANS* (CO) gene (Darwati, 2018).

5. Limited Knowledge, Skills, and Understanding of Forest Plants

Local knowledge regarding the cultivation and propagation of *C. argentea* and *C. tungurrut* is limited in the study area. The study on propagating *C. argentea* was carried out in vitro (Surya *et al.*, 2017), while the propagation of *C. tungurrut* has never been carried out. Propagation activities using the stem-cutting technique have also been carried out on *Castanopsis buruana*, but the results were unsuccessful because the experimental activities could not produce the roots (Arif *et al.*, 2021). Limited knowledge and skills in cultivating forest plants, such as *C. argentea* and *C. tungurrut*, make it challenging to restore forest ecosystems. The low natural regeneration of *C. argentea* and *C. tungurrut* should be balanced by ex-situ cultivation skills to preserve Indonesia's native plant species. One of the propagation methods that is currently being developed is using the KOFFCO (Komatsu-FORDA Fog Cooling System) by testing various plant parts, such as shoot cuttings and stem cuttings, especially from the Dipterocarp species (Rachmat *et al.*, 2018). Meanwhile, methods for propagating the *Castanopsis* species that have been considered successful include the stem cuttings method by adding potassium (K) salt of IBA (KIBA) with a success rate of up to 90% for *Castanopsis sclerophylla* (Conden & Blazich, 2003), and *C. hystrix* in China with in vitro regeneration technique that uses stem segments of the species as explants (Zhang *et al.*, 2022). Currently, with limited knowledge and skills in cultivating *Castanopsis* spp. in Indonesia, attention needs to be paid to creating propagation methods that are effective, efficient, low production costs, and easy to use so that communities around the forest can apply these propagation techniques.

Conservation and Sustainable Management Efforts

Conservation efforts—aimed at slowing the decline of *C. argentea* and *C. tungurrut* populations, especially within the Gunung Halimun-Salak National Park—involve gaining support from communities in the buffer villages. Several alternative conservation and management measures that can be implemented include enforcing rules to protect endangered plant species, efforts to propagate and reintroduce endangered plant species in ecosystem recovery areas and increasing dissemination and socialization about the importance of preserving flora and fauna in the forests of the Gunung Halimun-Salak National Park among the communities in the buffer villages.

The presence and role of communities in the buffer villages surrounding Gunung Halimun-Salak National Park in preserving the habitat and populations of endangered plants are crucial. Conservation efforts in the forest significantly affect the socio-cultural lives of these village communities. Residents living near the forest have a strong connection to it, creating a reciprocal relationship between the forest and the people (Yanto, 2013). The primary factor in community participation in collaborative conservation area management should be the close relationship between the community and the forest. This includes the community's reliance on forest resources, historical and socio-cultural ties of the local community, and the livelihoods of those living around the forest. When the community's reliance on these resources is acknowledged and met, it fosters an awareness among them to protect the forest and encourages a commitment to conserving the area (Qodriyatun, 2020). Therefore, effective communication and coordination between conservation area managers and the forest-dwelling community are essential. Furthermore, sharing information, functions, roles, and responsibilities fosters a healthy and productive partnership.

Improving the skills and proficiency of communities in cultivating rare plants, such as *C. argentea* and *C. tungurrut*, is a crucial step in preserving endangered plant species. The current challenge lies in the lack of information and success in propagating these species, posing a significant hurdle that requires an immediate solution. Enhancing the community's understanding and knowledge regarding the importance of *C. argentea* and *C. tungurrut* within the forest ecosystem chain is essential. This can encourage them to willingly plant these endangered plant species in the agricultural areas they tend around the forest corridor.

CONCLUSIONS

The communities in the buffer villages of Gunung Halimun-Salak National Park recognize the presence of *Castanopsis argentea* (*saninten*) and *C. tungurrut* (*tungurut*) in their surroundings. They can even distinguish between these two species. Their understanding and utilization of *C. argentea* and *C. tungurrut* stem from past activities involving frequent entries and exits from the forest and previous and current use of their parts, such as wood and fruits. Generally, their awareness of the species' scarcity is based on practical observations rather than legal regulations or conservation statuses. According to local knowledge, the causes of species scarcity can be categorized into internal and external factors. Internal factors include both species having a slow natural regeneration pattern, difficulties in germination, and vulnerable seedlings due to environmental conditions. External factors encompass seed and wood exploitation, habitat loss, climate changes, limited knowledge, skills, and understanding of forest plants, and the perceived lack of economic benefits from *C. argentea* and *C. tungurrut*, leading to the gradual neglect of their existence.

All related stakeholders, *i.e.* academics, businesses, governments, and communities, must be responsible hand-by-hand to the existence of *C. argentea* and *C. tungurrut* as native plants of Gunung Halimun-Salak National Park. Apart from that, there is also a need to educate the local people in the study area regarding current regulations of collecting plant species in the Gunung Halimun -Salak National Park. It would be a good step if all related stakeholders could raise awareness among the public by informing them of the protected plant species, the urgency, and the sanctions imposed.

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SIDA PENAMBANGENSIS (MALVACEAE), A NEW SIDA SPECIES FROM EAST JAVA, INDONESIA

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ABSTRACT
FELAYATI, T., RUSTIAMI, H. & SUSANDARINI, R. 2024. *Sida penambangensis* (Malvaceae), a new *Sida* species from East Java, Indonesia. *Reinwardtia* 23(1): 33–38. — A new species of *Sida* from Penambangan Village, Sidoarjo, East Java related to *Sida acuta* is described as *Sida penambangensis* Felayati, Rustiami & Susandarini. It is distinguished from *Sida acuta* Burm.f. with at least six characters such as stem covered with obvious long trichomes, reddish-purple at upper leaf margin, stipule subulate-falcate, pedicels not articulated, mericarps 9–11 with pair linear awns 0.8 mm long with simple and stellate pubescence. It is described and illustrated here as a species new to science.

Key words: East Java, Malvaceae, new species, *Sida penambangensis*, taxonomy.

ABSTRAK
FELAYATI, T., RUSTIAMI, H. & SUSANDARINI, R. 2024. *Sida penambangensis* (Malvaceae), jenis baru Sidaguri dari Jawa Timur, Indonesia. *Reinwardtia* 23(1): 33–38. — Jenis baru *Sida* berkerabat dengan *Sida acuta* dari Desa Penambangan, Sidoarjo, Jawa Timur dipertelakan sebagai *Sida penambangensis* Felayati, Rustiami & Susandarini. Jenis ini dibedakan dari *Sida acuta* Burm.f. berdasarkan setidaknya enam karakter yaitu batang ditutupi trikoma panjang yang jelas, berwarna ungu kemerahan pada tepi daun bagian atas, stipula '*subulate-falcate'*, tangkai daun tidak berartikulasi, merikarpium berjumlah 9–11 dengan sepasang tanduk berbentuk linier, panjang tanduk 0,8 mm dengan rambut sederhana dan berbentuk bintang. Jenis ini dipertelakan dan diilustrasikan sebagai jenis baru dalam ilmu pengetahuan.

Kata kunci: Jawa Timur, jenis baru, Malvaceae, *Sida penambangensis*, taksonomi.

INTRODUCTION

The species in the genus *Sida* L. (Linnaeus, 1753: 684) are widely distributed as weeds in the tropics and subtropics. *Sida* is one of the largest genera in subfamily *Malvoideae* (Grings & Boldrini, 2022) and tribe *Malveae* (Brandao *et al*., 2017), including 1730 species in the New World (Bayer & Kubitzki, 2003). *Sida* has undershrub habit with serrated margin leaf, solitary small flowers, one seeded schizocarp fruit with 5–14 mericarps, and the mericarp is trigonous with muticous to prominently aristate (van Borssum Waalkes, 1966; Brandao *et al*., 2017). The typical character of *Sida* in Java always has a yellow corolla (Backer & Bakhuizen van den Brink, 1963).

Previously, a taxonomic account of *Sida* in Java recorded by Backer & Bakhuizen van den Brink (1963) and van Borssum Waalkes (1966). Backer & Bakhuizen van den Brink (1963) recorded nine species of *Sida*, there are *S. acuta* Burm.f., *S. balica* Miq., *S. cordifolia* L., *S. glutinosa* Cav., *S. mysorensis* Wight & Arn., *S. retusa* L., *S. rhombifolia* L., *S. subcordata* Span., and *S. veronicifolia* Lam. In 1966, van Borssum Waalkes also recorded nine species in Java namely *S. acuta* Burm.f., *S. cordata* (Burm.f.) Borss.Waalk., *S. cordifolia* L., *S. elongata* Blume, *S. glutinosa* Comm. *ex* Cav., *S. javensis* Cav., *S. rhombifolia* L., *S. spinosa* L., and *S. subcordata* Span. but some species were different from the previous one. There are several species already synonymised such as *S. balica* Miq. synonym of *S. elongata* Blume., *S. retusa* L. synonym of *S. rhombifolia* subsp. *retusa* (L.) Borss.Waalk. and *S. veronicifolia* Lam. synonym of *S. cordata* (Burm.f.) Borss.Waalk. Only four species recorded from Java included in POWO that are *S. javensis* Cav., *S. rhombifolia* L.,

Table 1. Species of *Sida* recorded from Java based on previous taxonomic study in 1963 and 1966

Backer & Bakhuizen van den Brink (1963)	van Borssum Waalkes (1966)
S. acuta Burm.f.	*S. acuta* Burm.f.
S. balica Miq.*	*S. cordata* (Burm.f.) Borss.Waalk.
S. cordifolia L.	*S. cordifolia* L.
S. glutinosa Cav.	*S. elongata* Blume
S. mysorensis Wight & Arn.	*S. glutinosa* Comm. *ex* Cav.
S. retusa L.*	*S. javensis* Cav.
S. rhombifolia L.	*S. rhombifolia* L.
S. subcordata Span.	*S. spinosa* L.
S. veronicifolia Lam.*	*S. subcordata* Span.

*synonymised species.

Fig. 1. Collection site of *Sida penambangensis* Felayati, Rustiami & Susandarini.

S. rhombifolia var. *maderensis* (Lowe) Lowe and *S. subcordata* Span. as can be seen in Table 1.

A new species of *Sida* was found in the urban area of Penambangan Village, East Java. Field sampling was conducted in 2020, and this plant mostly found on roadsides and dry waterways. It is distinguished from *Sida acuta* Burm.f. with at least six characters such as stem covered with obvious long trichomes, reddish-purple at upper leaf margin, stipule subulate-falcate, pedicels not articulated, mericarps 9–11 with pair linear awns 0.8 mm long with simple and stellate pubescence. A new species propose here will contribute updating the diversity of Malvaceae in Indonesia since the last revision was made in 1966 by van Borssum Waalkes. Considering many species have been treated with new status taxonomically, updating the taxonomic status within the genera occurred in Java is needed .

MATERIALS AND METHODS

The species found at Penambangan Village, Sidoarjo, East Java. The type material deposited in Herbarium Bogoriense (BO) (herbarium codes follow Thiers 2020+). The description were made

Fig. 2. Holotype of *Sida penambangensis* Felayati, Rustiami & Susandarini, showing stem, leaf, non anthesis flower and schizocarp.

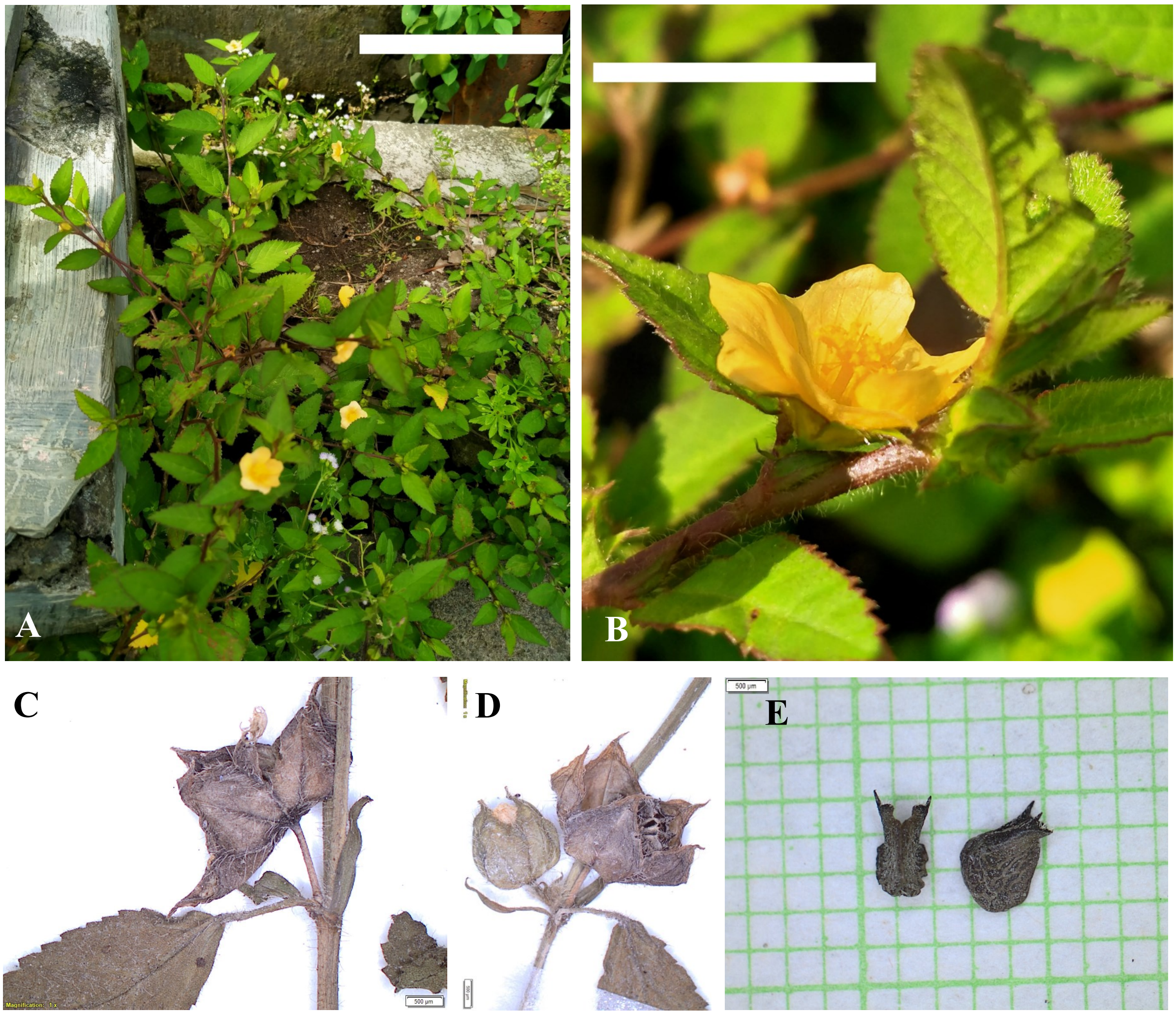

Fig. 3. *Sida penambangensis* Felayati, Rustiami & Susandarini. A. Habit. B. Flower showing staminal column and detail of simple, prominent and long hairs on branch. C. Detail of the vein of the stipules and non-articulated pedicel. D. Detail of glabrous until puburulent pedicel, virogously pilose calyx and small tomentose lump. E. Mericarpium showing trichomes on awn or aristate. Scale bar: A= 20 cm; B= 2 cm; C-E= 500 µm. Photos by Themas Felayati.

through examination of herbarium specimens of genus *Sida* deposited in BO. The terminology of structure following van Borrsum Waalkess (1966), Brandao *et al.* (2017) and Beentje (2010). The map was made in https://www.simplemappr.net/.

RESULTS AND DISCUSSION

Sida penambangensis Felayati, Rustiami & Susandarini, *spec. nov.* Figs. 2 & 3 — TYPE: INDONESIA: East Java Province: Sidoarjo Regency, Balongbendo District, Penambangan Village, 7° 24'23.6"S 112°31'56"E, 15 m, 29 January 2020. *Felayati 2* (Holotype: BO!).

Sida penambangensis has several diagnostic characters such as stem covered with obvious long trichomes, reddish-purple at upper leaf margin, stipule subulate-falcate, pedicels not articulated, mericarps 9–11 with pair linear awns 0.8 mm long, awns simple and stellate pubescence.

Scandent undershrubs, 60–100 cm height. *Stem* terete, green suffused with reddish-purple, covered with simple, prominent and long trichomes. *Stipules* subulate-falcate or subfalcate, 2 veins, 0.4–0.7 × *ca.* 0.1 cm, adaxial surface green-yellow, abaxial surface red purplish, 4–5-nerved, long ciliate along the margins. *Leaves*: petiole 0.5–0.7 cm long, pubescent, stellate hair, reddish-purple; blade ovate to lanceolate, 2.5–2.8 × 1.5–1.6 cm, base rounded-subcordate, apex acuminate, margin serrate almost to the base, green-yellow and reddish-purple at upper margin sparsely stellate hairy above and more or less densely beneath; lateral nerves 5–8 pairs. *Flowers* axillary, solitary, *ca.* 3

Table 2. Comparison of diagnostic morphological characters of *Sida acuta* and *S. penambangensis*

Characters	*Sida acuta*	*Sida penambangensis*
Branchlets surface	Stellate hairs	Long simple hairs
Adaxial leaf margins	Green coloured	Reddish-purple coloured
Leaf apex	Acute	Shortly acuminate
Stipules	Linear-lanceolate	Subulate-falcate
Pedicels	Articulated	Not articulated
Mature mericarps colour	Broken-white coloured	Black coloured

Key to the species of *Sida* spp. in Java are presented here.

1	a	Leaf palminerved; base deeply cordate …….......................................	2
	b	Leaf penninerved; base subcordate to rounded ………………………	4
2	a	Procumbent herbs, staminal column pubescens ……………............	3
	b	Erect shrubs, staminal column glabrous ………………………….....	*S. mysorensis*
3	a	Mericarps awnless, long triangular calyx ……………………………..	*S. elongata*
	b	Mericarps awned, short triangular calyx …………………………….......	*S. javensis*
4	a	Stipules subfalcate, short pedicel……………………………………....	5
	b	Stipules filiform, long pedicel …………………………………........	6
5	a	Pedicel articulated, mature mericarp broken-white coloured ………....	*S. acuta*
	b	Pedicel not articulated, mature mericarp black coloured ……………..	*S. penambangensis*
6	a	Leaf blade cordate, velutinous leaf surface ………………………........	*S. cordifolia*
	b	Leaf blade not cordate, non velutinous leaf surface..................………	7
7	a	Number of mericarps more than five, spine absent …………………	8
	b	Number of mericarps five, spine present ……………………………..	*S. spinosa*
8	a	Leaf blade rhomboid to lanceolate, awn length less than 2 mm ……..	*S. rhombifolia*
	b	Leaf blade ovate, awn length more than 2 mm …………………........	*S. subcordata*

cm across, yellow. *Pedicels* 0.3–0.4 cm long, not-articulated, glabrous to pubescent. *Calyx* 10 ribbed from the base, campanulate, 5-lobed; lobes ovate, 0.7–0.8 cm long, apex acute-acuminate, margins ciliate, vigorously pilose. *Corolla* 2.5–3 cm across, yellow; petals obliquely ovate, to 1 × 0.7 cm, base cuneate, glandular hairy at abaxial and adaxial. *Staminal column* to 2 mm long, monadelphous, glabrous. *Ovary* ovoid, minutely hairy towards the apex; styles 9–11; stigma capitate. In the axils, along with the petioles, pedicles and stipules, there is small tomentose lump. *Mericarps* 9–11, trigonous, each to 2 × 2 mm, enclosed in the calyx, black when mature, prominently reticulate and transversely rugose on sides and dorsal, apex with a pair of linear divergent awns of 0.8 mm long, pubescent. *Seeds* reniform, flattened, *ca.* 1.3 mm high, brownish-black, glabrous except for the pubescent hilum at apex of seed.

Distribution. *Sida penambangensis* so far is only known from type locality (Fig. 1).

Ecology & Habitat. *Sida penambangensis* is found in the lowlands at altitudes between 10–15 m asl. The species is commonly occurred at roadsides and in a dry waterway. The main associated species are *Scoparia dulcis* L. (Plantaginaceae) and *Ageratum conyzoides* L. (Asteraceae). Flowering and fruiting throughout the year.

Etymology. The specific epithet is based on the type locality of the taxon, Penambangan village.

Conservation status. Based on IUCN (2012), this species categorized in Data Deficient (DD) because the appropriate data on abundance and distribution of this species are lacking. The species only found from type locality.

Notes. This species can be distinguished from the rest of the species by its clearly visible long simple trichomes on the branchlets and larger size of the flowers. The flowers open at 9 am and close at noon. *Sida penambangensis* is related to *Sida acuta* and likely belongs to section Distichifolia (Monteiro) Krapov. based on several characters such as distichous lateral branches, stipule subfalcate, short pedicels, mericarps more than five and a pair of awns. The petiole is articulated according to Brandao *et al*. (2017), but in van Borrsum Waalkess (1966) it is known as jointed. In line with Krapovickas (2003), *Sida* section Distichifolia has erect shrubs or subshrubs, cylindrical central axis, with spiral branching, distichous lateral branches, usually with flattened stem, leaves elliptic, crenate-serrate, shortly petiolate, stipules subfalcate, dimorphic, with 1–6 nerves, short peduncles, corolla yellow, sometimes white, mericarps 5 –12, submuculate to bi-aristate, laterally reticulate.

Van Borssum Waalkes (1966) and Fryxell (1985) placed *Sida acuta* in section *Sida.* Currently, *Sida acuta* is treated in section Distichifolia based on distichous branching, subfalcate stipules and relative length of articulated petiole and pedicels, petiole equal or longer than pedicels (Krapovickas, 2003; Brandao *et al*., 2017). *Sida penambangensis* is considered to be included in the section Distichifolia and is distinguished from *Sida acuta* by branching surface, leaf margin, leaf apex, stipules, petiole, and mature leaf colour (Table 2).

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BEGONIA TANGGAMUSENSIS, A NEW SPECIES OF *BEGONIA* SECT. *PLATYCENTRUM* FROM GUNUNG TANGGAMUS, SUMATRA AND NOTES ON ALLIED SPECIES *BEGONIA SCOTTII* AND *BEGONIA PSEUDOSCOTTII*

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ABSTRACT
HUGHES, M. & GIRMANSYAH, D. 2024. *Begonia tanggamusensis*, a new species of *Begonia* sect. *Platycentrum* from Gunung Tanggamus, Sumatra and notes on allied species *Begonia scottii* and *B. pseudoscottii*. *Reinwardtia* 23 (1): 39–43. — A new species, *Begonia tanggamusensis* Girm. & M.Hughes (§ *Platycentrum*), is described from Gunung Tanggamus in southern Sumatra, where it is endemic. It grows on moss covered rocks and at the base of large trees in montane forests at an elevation of 1,700–2,000 m. A provisional conservation assessment places the species in the Near Threatened category.

Key words: *Begonia*, conservation, endemic, moss, Tanggamus.

ABSTRAK
HUGHES, M. & GIRMANSYAH, D. 2024. *Begonia tanggamusensis*, jenis baru *Begonia sect. Platycentrum* dari Gunung Tanggamus, Sumatra dan catatan jenis terdekatnya *Begonia scottii* dan *B. pseudoscottii*. *Reinwardtia* 23(1): 39–43. — Jenis endemik baru, *Begonia tanggamusensis* Girm. & M.Hughes (§ *Platycentrum*), dipertelakan dari Gunung Tanggamus di Sumatra bagian selatan. Jenis ini tumbuh di bebatuan yang tertutup lumut dan di bawah pohon besar di hutan pegunungan pada ketinggian 1.700–2.000 m. Penilaian konservasi sementara menempatkan jenis ini dalam kategori terancam punah.

Kata kunci: *Begonia*, endemik, konservasi, lumut, Tanggamus.

INTRODUCTION

The genus *Begonia* is currently undergoing a rapid phase of taxonomic discovery in Southeast Asia, due to regional checklists (Hughes *et al.*, 2015b, 2020; Pham *et al.*, 2021) and increased activity by regional taxonomic specialists. Sumatra in particular has seen many species new to science published in recent years (Ardi *et al.*, 2021; Ardi & Hughes, 2010, 2018; Girmansyah, 2012; Girmansyah *et al.*, 2020, 2022; Hughes *et al.*, 2009, 2015a; Tebbitt, 2005), bringing the total number of accepted species from the island to 79, of which 72 are endemic. During a joint expedition in 2016 between the Research Centre for Biology in Cibinong and the Royal Botanic Garden Edinburgh, a *Begonia* was found and collected on Gunung Tanggamus in Lampung Province, southern Sumatra. It was tentatively identified as *Begonia scottii* Tebbitt at the time of collection, but as it was sterile a cutting was taken for cultivation. Upon flowering in cultivation at the Royal Botanic Garden Edinburgh over a year later, several differences were noted between the plant and *B. scottii*, and it was then identified as a species new to science which is described here as *Begonia tanggamusensis* Girm. & M.Hughes (Fig. 1). As the species has a large androecium, anthers with extended connectives, and fleshy indehiscent fruit, it belongs to sect. *Platycentrum*. It differs from *B. scottii* (Tebbitt, 2005) (Figs. 2 & 3) chiefly in being glabrous (not softly hairy on the stem, leaves, and ovaries) and having much larger inflorescences of *ca.* 30 flowers (not *ca.* 5 flowers). We have included two images of *B. scottii* from different locations to show the variation of this widespread species. Also allied is *Begonia pseudoscottii* Girm. (Hughes *et al.*, 2015a) (Fig. 3), which shares large inflorescences and clusters of fruits, however *B. tanggamusensis* differs chiefly in being glabrous (not softly hairy on the stem and leaves) and having infructescences borne on a peduncle *ca.* 7 cm long on an arial stem (not almost sessile at the base of the plant); see Table 1 for a comparison of all three species.

Table 1. A comparison of the key distinguishing characters for *Begonia pseudoscottii*, *B. scottii*, and *B. tanggamusensis*.

	Leaf vestition	Fruits per inflorecence	Inflorescence position	Primary peduncle length	Fruit
B. pseudoscottii	Red hairs	10–15	Basal	*ca.* 1 cm	Purple, glabrous, 3 equal ridges
B. scottii	White hairs	2	Axillary	2–7 cm	Green, hairy, 3 short wings
B. tanggamusensis	Glabrous	8–12	Axillary	7 cm	Reddish-green, glabrous, one ridge enlarge

RESULTS AND DISCUSSION

Begonia tanggamusensis Girm. & M.Hughes *spec. nov.* § Platycentrum. Fig. 1. — TYPE: INDONESIA. Sumatra, Lampung, Gunung Tanggamus, 1,938 m elevation, growing at the foot of moss covered trees, 5°25'33.5" S, 104°40'44.5" E, 6 February 2016, *Hughes, M., Barber, S., Girmansyah, D. & Kartonegoro, A. SUBOE80* (Holotype: BO!, isotype: E!), pressed from a cultivated specimen at RBGE [accession 20170076].

A robust herb. *Stem* rhizomatous, *ca.* 3 cm diameter, red, glabrous, internodes *ca.* 1 cm long; arial stems arising from the rhizome, 10–15 cm long, reddish green with pale lenticels, succulent, *ca.* 1 cm diameter. *Stipules* triangular, 3 × 1 cm, reddish green, glabrous, slightly keeled, aristate. *Petioles* 15–45 cm long, succulent, reddish green at the base, green at the apex, glabrous, *ca.* 1 cm diameter at the base, becoming more slender at the top. *Leaves* 14–23 × 10–17 cm, ovate, asymmetric; upper surface dark green with purple mottling between the veins; lower surface pale green; margin repand, denticulate; main veins 7–9, venation palmate, raised above and prominent below. *Inflorescences* with *ca.* 30 flowers, bisexual, protandrous, primary peduncle *ca.* 7 cm long, secondary 1–2 cm long, tertiary and further branching much reduced giving the appearance of two globose heads of flowers. *Bracts* ovate, boat-shaped, tip acute, translucent green, glabrous, *ca.* 2 × 1 cm at the base of the inflorescence, becoming smaller toward the apex. *Staminate flowers*: pedicels 1.5 cm long, glabrous, pinkish white to red; tepals 4, white, outer 2 elliptic, boat shaped, 2 × 1.7 cm, inner 2 elliptic-obovate, 1.7 × 1 cm; androecium cylindrical, with *ca.* 100 stamens, on a stout short column, stamens *ca.* 5 mm long; filaments 3 mm long; anthers 2 mm long, connective extended, acute-rounded, dehiscing through lateral slits almost as long as the anther. *Pistillate flowers*: pedicel *ca.* 1 cm, glabrous, pinkish white to red; tepals 5, outer two pinkish white, inner three paler pinkish white to white, elliptic, 2 × 1.5 cm; styles three, free, bifid, stigmatic surface greenish yellow, highly convoluted; ovary green, *ca.* 1 × 1.5 cm, with 3 fleshy ridges, three-locular, placentae bifid. *Fruits* fleshy and succulent, indehiscent, green with red spots, *ca.* 1.5 × 2 cm, with 3 fleshy ridges, one ridge larger and more wing-like, *ca.* 8 mm across, borne in clusters of 8–12.

Other Specimen Examined. SUMATRA. Lampung, Gunung Tanggamus, 1,636 m elevation, in diverse montane forest with rattans, 5°25'30" S, 104°41'1" E, 4 February 2016, *Hughes, M., Barber, S., Girmansyah, D. & Kartonegoro, A. SUBOE79* (BO, E).

Distribution. Endemic to Gunung Tanggamus, Lampung Province, Sumatra. Known from two localities represented by collections Hughes *et al.* *SUBOE79* & *SUBOE80*, at elevations of 1,336 m and 1,938 m respectively.

Habitat and Ecology. In montane and cloud forest, growing on damp moss covered rocks or at the base of moss-covered tree trunks.

Etymology. After the type locality of Gunung Tanggamus.

Provisional Conservation Assessment. We assess *Begonia tanggamusensis* as Near Threatened according to IUCN criteria (IUCN Standards and Petitions Committee, 2022). It is only known from two small populations, however given the exent of montane forest on Gunung Tanggamus it is highly likely there are many more. Currently there are no plausible threats that would cause population decline, as the type locality is a protected area (Muhaimin *et al.*, 2018). However the mountain is deforested up to an altitude of *ca.* 1,100 m in places, and *B. tanggamusensis* occurs *ca.* 1.4 km upslope from this edge. Any further encroachment would lead to the species becoming Vulnerable.

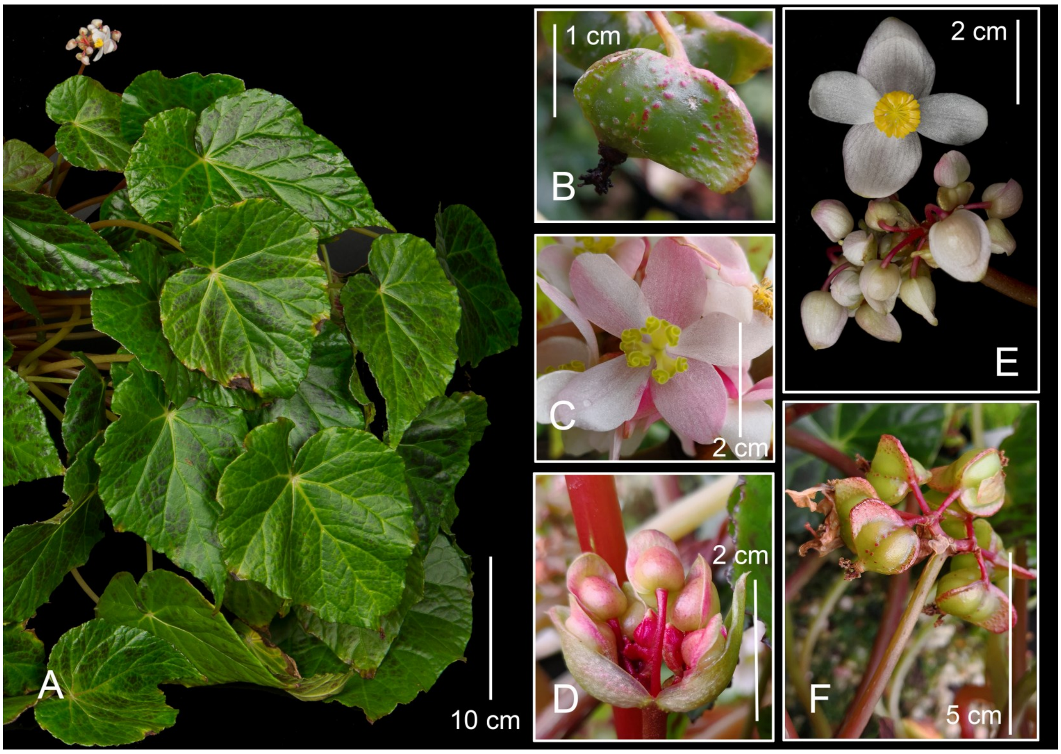

Fig. 1. *Begonia tanggamusensis* Girm. & M.Hughes. A. Habit. B. Ripe fruit. C. Pistillate flower. D. Young inflorescence with bracts subtending. E. Young inflorescence and open staminate flower. F. Infructescence. Photographs taken from a plant in cultivation at the Royal Botanic Garden Edinburgh [accession 20170076] derived from *Hughes et al. SUBOE80*. Photos by Mark Hughes.

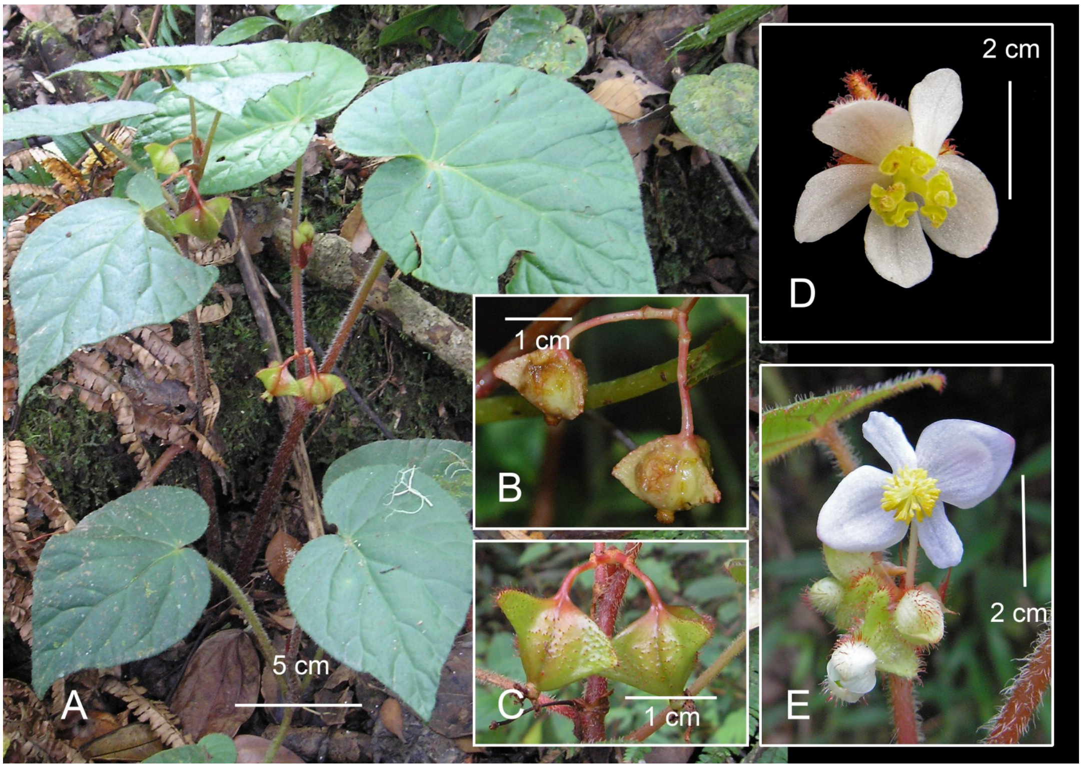

Fig. 2. *Begonia scottii* Tebbitt. A. Habit. B & C. Ripe fruits. D. Pistillate flower. E. Young inflorescence and staminate flower. Photographs A, C, D, & E from material collected from Gunung Merapi, West Sumatra (*Girmansyah et al. DEDEN772* (BO, E)); B from a plant on Gunung Sorik Marapi in North Sumatra (no voucher). Photos by Mark Hughes (B), Deden Girmansyah (A, C, D & E).

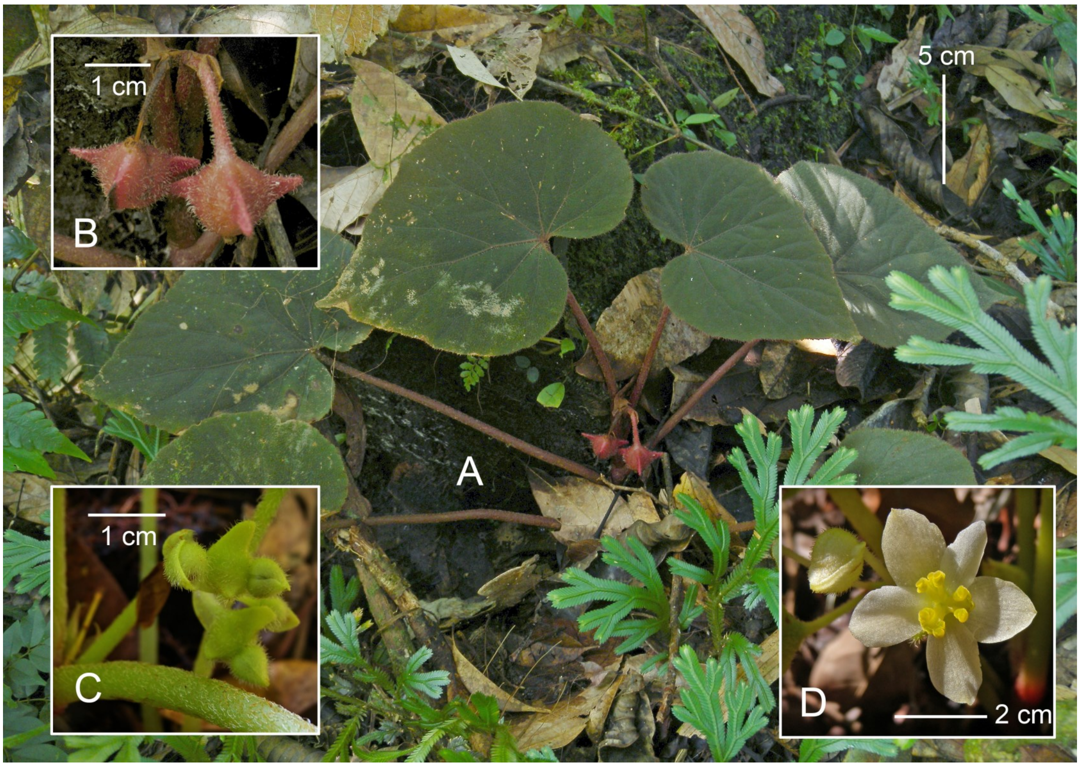

Fig. 3. *Begonia scottii* Tebbitt. A. Habit. B Ripe fruits. C. Young inflorescence with pistillate flowers in bud. D. Pistillate flower. Photographs from material collected from Gunung Kemumu, Bengkulu; A & B from *Puglisi et al. CP184* (BO, E); C & D from *Puglisi et al. CP217* (BO, E). Photos by Mark Hughes.

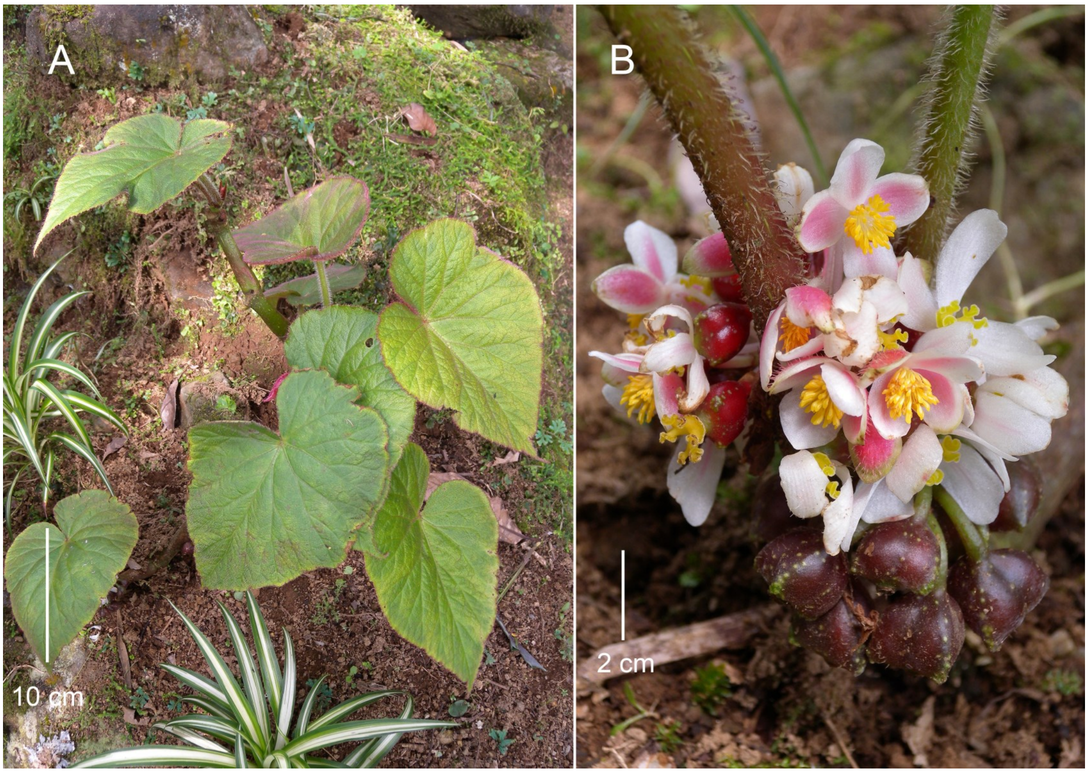

Fig. 4. *Begonia pseudoscottii* Girm. A. Habit. B. Infructescence and inflorescence with pistillate and staminate flowers. Photographs from a plant cultivated in Cibodas Botanic Garden (accession number C20090980/IY80, derived from material collected in Gunung Leuser National Park). Photos by Deden Girmasyah.

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LEAF ANATOMICAL ADAPTATION OF EXOTIC INVASIVE *MICONIA CRENATA* (VAHL) MICHELANG. ALONG AN ELEVATION GRADIENT: A CASE STUDY OF MOUNT GEDE-PANGRANGO NATIONAL PARK, WEST JAVA, INDONESIA

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ABSTRACT
JUNAEDI, D. I., TIHURUA, E. F., WIDOYANTI & GIRMANSYAH, D. 2024. Leaf anatomical adaptation of exotic invasive *Miconia crenata* (Vahl) Michelang. along an elevation gradient: a case study of Mount Gede-Pangrango National Park, West Java, Indonesia. *Reinwardtia* 23(1): 45–54. — *Miconia crenata* is a widely spread species that occurs in multiple ecosystems. However, there is limited information on *M. crenata* invasion biology, ecology, and anatomy, particularly in the context of mountainous tropical forest and biodiversity management. Therefore, we examined elevation effects upon leaf anatomical structure of exotic invasive *M. crenata* at Mount Gede-Pangrango National Park (MGPNP). We sampled the leaves at four different elevations *i.e.,* 715 m asl, 800 m asl, 900 m asl, and 1,000 m asl. Cross section leaf anatomy specimens of *M. crenata* were obtained by using paraffin method and stained with safranin and fast green. This study found that *M. crenata* leaf anatomy was correlated with elevation shown by changes in leaf tissue thickness and stomata size. Further study is needed of leaf anatomical variation of exotic invasive species along driven by soil properties and the variation across different plant taxa and growth forms. Such studies are important to determine adaptation capacity of invasiveness.

Key words: Biodiversity management, elevation, invasive species, *Miconia crenata*, Mount Gede-Pangrango, tropical forest.

ABSTRAK
JUNAEDI, D. I., TIHURUA, E. F., WIDOYANTI & GIRMANSYAH, D. 2024. Adaptasi anatomi daun asing invasif *Miconia crenata* (Vahl) Michelang. sepanjang gradien ketinggian: sebuah studi kasus Taman Nasional Gunung Gede-Pangrango, Jawa Barat, Indonesia. *Reinwardtia* 23(1): 45–54. — *Miconia crenata* merupakan jenis yang tersebar luas dan dapat hidup di kondisi ekosisteam dan ketinggian yang berbeda. Namun demikian, informasi mengenai invasi biologis *M. crenata*, meliputi biologi, ekologi, dan anatomi masih terbatas, terutama yang menyangkut pengelolaan keanekaragaman di hutan pegunungan tropis. Oleh karena itu, studi ini dilaksanakan untuk meneliti variasi struktur anatomi daun jenis asing invasif *M. crenata* pada beberapa ketinggian di Taman Nasional Gunung Gede-Pangrango (TNGGP). Sampel daun jenis tersebut dikumpulkan pada empat ketinggian berbeda yaitu, 715 m dpl, 800 m dpl, 900 m dpl, dan 1.000 m dpl. Irisan melintang daun *M. crenata* didapatkan dengan menggunakan metode parafin dan diwarnai dengan *safranin* dan *fast green*. Studi ini menunjukkan bahwa anatomi daun *M. crenata* berkorelasi dengan ketinggian yang diindikasikan oleh perubahan ketebalan daun dan ukuran stomata pada ketinggian berbeda. Penelitian lebih jauh mengenai anatomi jenis asing invasif pada variasi ketinggian dan habitat, bentuk hidup pada taksa yang berbeda sangat penting dilakukan untuk mengetahui kemampuan adapatasi yang berkaitan dengan tingkat keinvasifan suatu jenis.

Kata kunci: Hutan tropis, jenis invasif, ketinggian, *Miconia crenata*, pengelolaan keanekaragaman hayati, Taman Nasional Gunung Gede-Pangrango.

INTRODUCTION

Miconia crenata (Vahl) Michelang. (Mabberley, 2017) is included in the Melastomataceae family and is naturally distributed in Mexico to Tropical America. It is considered an exotic species in Indonesia and Asia more widely (Wester & Wood, 1977; Junaedi *et al.*, 2021; Holmes *et al.*, 2023). *Miconia crenata* is one of the 100 worst invasive alien species in the world (GISD, 2023). *M. crenata* has dispersed as an exotic invasive species into many native ecosystems of Asia and Africa (Rojas-Sandoval & Acevedo-Rodríguez, 2014; Judd *et al.*, 2018).

Miconia crenata is perennial and usually grows in the form of a densely-branched shrub. The species' height tends to range from 0.5 m to 3 m but may grow up to 5 m tall. Most part of the plant are hairy and the leaves have prominent veins. The flowers are 0.5 cm to 1 cm in size, the fruits are berry-type, and the weight of 1,000 dried seed is 3.83 grams (Mune & Parham, 1967; Wickens, 1975; Francis, 2004). *Miconia crenata* has become an invasive species in many regions due to its reproductive characteristics. Firstly, *M. crenata* produces many seeds, resulting in a large soil seed bank size (Rojas-Sandoval & Acevedo-Rodríguez, 2014). Secondly, the fruit of this species is commonly eaten and dispersed by many animals, particularly bird species (Weber, 2003).

Miconia crenata invades multiple ecosystems, including those at both high and low elevations. There are currently limited studies on the invasion of *M. crenata* using ecophysiological and anatomical traits. Previous studies of *M. crenata* have mostly focused on their occurrence as an exotic invasive species (Peters, 2001; De Walt *et al.*, 2004a; Le *et al.*, 2018), the biomass allocation and genetic comparison between native and invasive ranges (De Walt *et al.*, 2004b; De Walt & Hamrick, 2004), and seed and seedling studies (Brooks *et al.*, 2018; Wanigasinghe & Gunaratne, 2020; Chandima *et al.*, 2022). Trait-based studies of invasive *M. crenata* have been conducted in the highlands of Java (Junaedi *et al.*, 2021) and lowlands of Borneo (Waddell *et al.*, 2020). Anatomical and morphological explanations of this species' adaptation as a successful invasive remain limited. The ecological, physiological, and anatomical information of *M. crenata* is crucial for invasive species management to protect biodiversity in mountainous tropical forests such as those in Indonesia, which contain many threatened, and endemic species (Higginbottom *et al.*, 2019; Utteridge *et al.*, 2024).

The Mount Gede-Pangrango National Park (MGPNP) is one of the important protected areas in Java, due to its rich and threatened biodiversity (Padmanaba *et al.*, 2017). Previous studies on invasive plant species in MGPNP have focused on detection of exotic invasive species (Tjitrosoedirdjo & Veldkamp, 2008; Uji *et al.,* 2010; Kudo *et al.*, 2014; Padmanaba *et al.*, 2017; Junaedi *et al.*, 2018), invasive species risk assessment (Junaedi & Mutaqien, 2018; Junaedi *et al.*, 2021a), and trait-based invasion ecological studies (Junaedi *et al.*, 2021b). These studies are crucial for providing sufficient information for relevant stakeholders regarding the threat and potential development of invasive plant species in MGPNP. Invasive species are considered as one of the main causes of ecosystem degradation and biodiversity loss ((IUCN, 2017; Dueñas *et al.*, 2021; Holmes *et al.*, 2024).

This study aims to examine the altitudinal variation in the leaf anatomical structure variation of exotic invasive *M. crenata.* We conducted a case study at Mount Gede-Pangrango National Park (MGPNP) for two main reasons. First, MGPNP is an important conservation area in Java, containing the typical mountainous forests of the western part of Java. Studying the ecology and biology of invasive species is therefore essential to minimize the risk and impact of invasive species occurrence in MGPNP. Secondly, previous studies have identified that *M. crenata* is a problematic invasive species in both lowland and highland forests of MGPNP (Loke *et al.*, 2023). Plant ecophysiological adaptation to altitudinal variations has been detected by previous studies (Rahman *et al.,* 2020). The anatomical aspect of invasive species studies will support a comprehensive understanding of the invasion mode of *M. crenata* to aid risk assessment and future management. Anatomical aspect provides a proxy to explain invasive plant species adaptation to its invaded habitat condition. The changes in plant anatomical structure and tissues may indicate the existing and ongoing inherent biological and ecophysiological proccess within the studied invasive plants. Finally, these biological and ecophysiological information can be utilized by relevant stakeholders and management authorities to decide the accurate management strategies to manage these invasive species.

MATERIALS AND METHODS

Study Area

The leaf samples and specimens of *M. crenata* were collected from 17 to 24 October 2022 from Mount Gede-Pangrango National Park (MGPNP), at Bodogol Resort Area from four sampling locations at different elevations (-6.77631 E, 106.85 574 S). These elevations are: 715 m asl, 800 m asl, 900 m asl, and 1,000 m asl. The leaf samples were collected from the area around the hiking trail because *M. crenata* occurs in relatively open area at MGPNP. The plants sampled were detected within 0–10 m of the hiking trail. Two individuals were sampled from each elevation. For each individual sample, at least four leaves were sampled for anatomical examination and specific leaf area measurement. The leaves were sampled following Perez -Harguindeguy *et al.* (2016), ensuring the leaves were healthy, not too young and not too old. Before being processed in the laboratory, the leaf samples were stored in 70% alcohol solution.

Anatomical Preparation

The cross-section leaf anatomy specimens of *M. crenata* were obtained using the modified paraffin method (Sass, 1951). Leaf specimens of 1 cm × 0.5 cm size were fixed in FAA solution (Ethanol 96%, Formalin, Acetic Acid, and Aquades). The fixed specimens were then dehydrated by using ethanol absolute, serial mix solution ethanol:tert-Butanol (3:1), ethanol:tert-Butanol (1:1), ethanol:tert-Butanol (1:3), and absolute tert-Butanol. The samples were further infiltrated by liquid paraffin with a melting point of 56–58°C, then embedded with paraffin (with similar melting point). The embedded samples were cut with a rotary microtome with a thickness of 14–16 µm. The sections were stained using 1% of safranin in 70% ethanol and 2% of fast green in absolute ethanol. Finally, the slides were covered by cover glass in mounting entellan media. The leaf surface micro morphology specimens were obtained by dipping the leaf sample with 1 cm × 1 cm in size in a warmed HNO_3 solution (Cutler, 1978) until the upper and lower surfaces of *M. crenata* leaves were separated. The mesophyll was then cleaned and dyed with safranin. Then, samples were placed on an object glass with the addition 1–2 drops of glycerin. Finally, the specimens were covered by using cover glass.

Anatomical Observation

The observation and measurement of anatomical characters of *M. crenata* leaves were conducted using Nikon eclipse 80*i* microscope. The observed leaf tissue anatomical parts included the thickness of upper and lower epidermis tissue layer, leaf palisade tissue, sponge tissue, stomata size and stomata density. Observation measurements for each leaf tissue part were repeated 10 times for each observed individual specimens, resulting in a total of 40 observation for each trait at every elevation.

Anatomical Traits vs Habitat

The correlation of all collected anatomical data variables was calculated using Pearson correlation analysis that was conducted in R studio and R 4.3.0 (R Core Team, 2020). Then we checked and choose suitable variables that were included in the linear model. We choose the variable in a way that highly correlated explantory variables were not included in the model simultaneously to avoid confounding factor in the model. A regression model between significantly correlated anatomical variables and elevation was performed using linear regression analysis, also in Rstudio and R 4.3.0 (R Core Team, 2020). The visualization of the correlation matrix and results of Pearson correlation analysis was conducted in “corrplot” package (Wei & Simko, 2021).

RESULTS

Miconia crenata stomata are found exclusively on the lower surface of the leaf (hypostomatic). The stomata type of *M. crenata* is anomocytic (Fig. 1B), meaning that the stomata are surrounded by cells that closely resemble the epidermal cells. The epidermis at the upper leaf side exhibit variety in anticlinal cell wall, namely straight, undulate, and sinuous wall (Figs. 1A–C). On the other hand, the lower side of the leaf’s epidermis has anticlinal sinuous wall (Figs. 1A & 1B). Non-glandular trichomes (shown in Fig. 1E) and glandular trichomes (shown in Fig. 1F) throughout the upper and lower surfaces of the leaf. The non-glandular trichomes (Fig. 1E) are stellate hair and simple and multicellular structure. The glandular trichomes (Fig. 1F) are pilate consisting of a long stalk with multicellular head cells.

Miconia crenata possesses a single layer of epidermis tissue on both surfaces of the leaf. The leaf mesophyll is composed of palisade tissue at the upper part and sponge tissue at the lower part (Fig. 2). The palisade tissues that collected from an elevation 715 m asl tend to have a cylindric shape (Fig. 2A) and consist of 1–2 layers. On the other hand, *M. crenata* leaves collected from elevations of 800, 900, and 1,000 m asl showed one layer palisade tissue with funnel shaped (Figs. 2B–D). The *M. crenata* leaf also contains druse-shaped $CaCO_3$ crystals which are scattered throughout the leaf mesophyll (Fig. 2A).

Anotomical differences in the leaves of *M. crenata* were observed at varying elevation. These differences did not arise in the tissue structure, but rather in the size of the tissues in the leaves. There are notable variations in the thickness of the upper epidermis, mesophyll, and the size of stomata (Table 1).

The stomata of *M. crenata* at an elevation of 715 m asl are the shortest, measuring with range 15.46 and 20.38 µm. In contrast, *M crenata*, which resides at an elevation of 1,000 m asl, has the longest stomata, ranging from 16.52 to 22.16 µm. At the highest altitude *M. crenata* possess the narrowest measuring between 13.65 and 18.34 µm, whereas the widest are owned by individuals at the lowest altitude (13.98–19.51 µm). The stomatal density of *M. crenata* tend to decrease as the altitude increases (Fig. 3). The *M. crenata* at highest altitude have a stomatal density ranging from 159 to 334 stomata/mm^2, while at the lowest altitude have the highest stomatal density ranging from 298 to 754 stomata/mm^2.

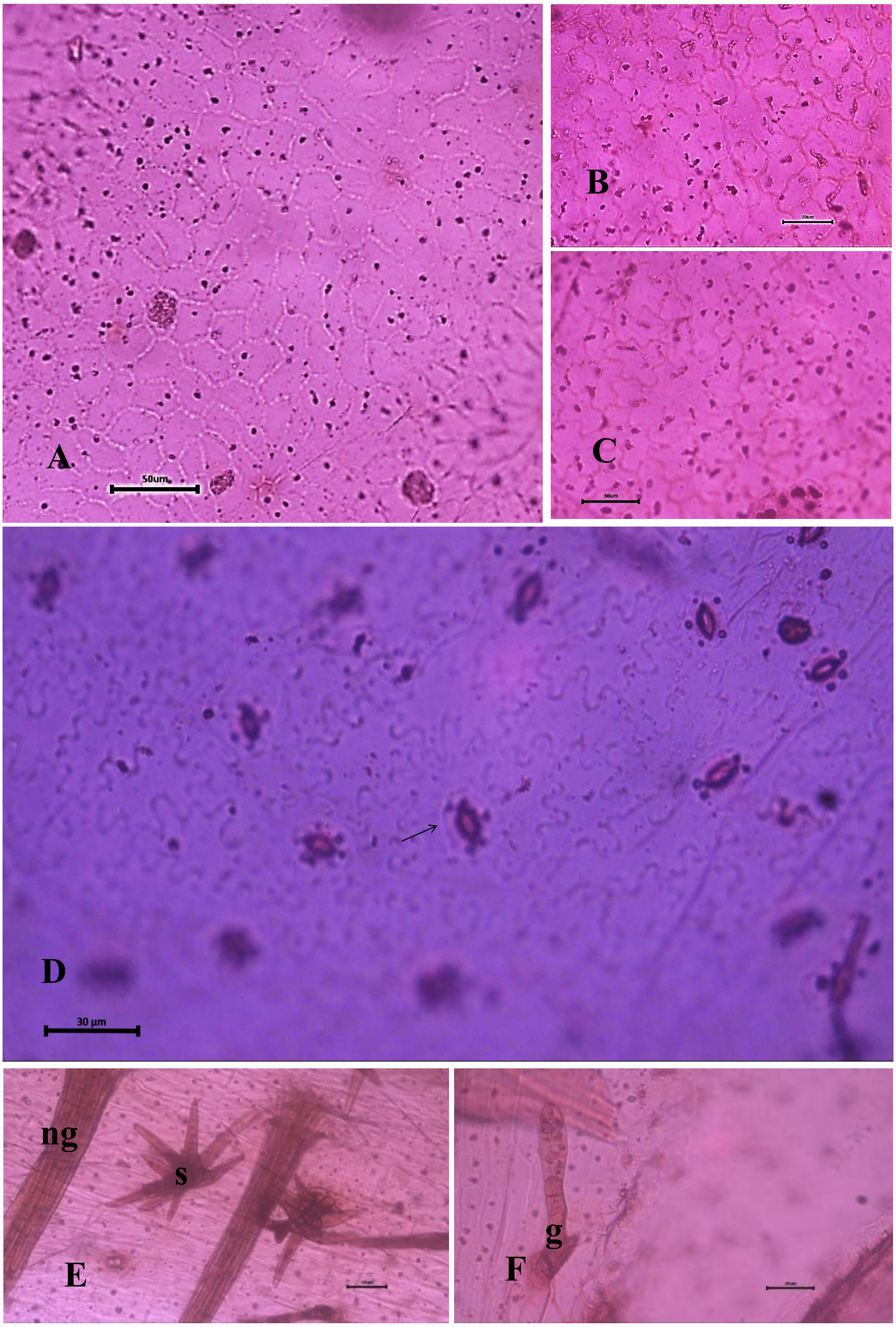


Fig. 1. Leaf surfaces of *Miconia crenata*. A-C. Upper leaf surface. A. Straight anticlinal cell wall. B. Undulate anticlinal cell wall. C. Sinuous anticlinal cell wall. D. Sinuous anticlinal cell wall in the lower surface of the leaf. E-F. Trichomes of *M. creanata*. Anomocytic stomata (arrow sign) that only occur at the lower side of the leaf of *M. crenata*. Non-glandular trichomes with stellate shape (s), simple and multicellular type (ng), and glandular trichomes, pilate type (g). Scale bar: 30 µm (B, C, D & F), 50 µm (A & E).

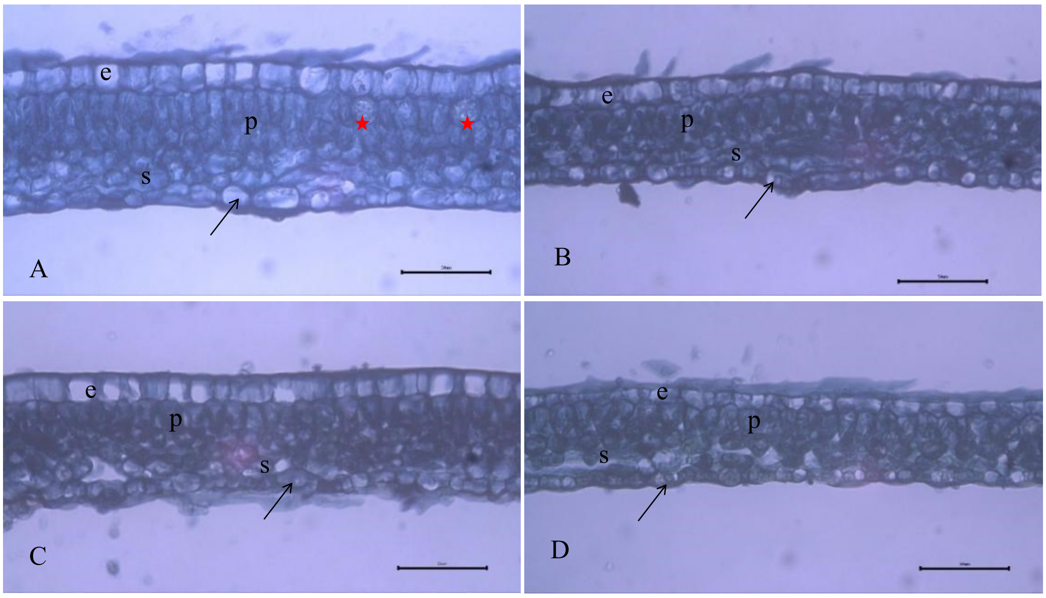


Fig. 2. Cross section of *Miconia crenata* leaf samples from four elevation. A. 715 m asl. B. 800 m asl. C. 900 m asl. D. 1000 m asl. ea: upper epidermis; p: palisade tissue; s: sponge tissue; red arrow: lower epidermis; star: druse crystal. Scale bar: 50 µm.

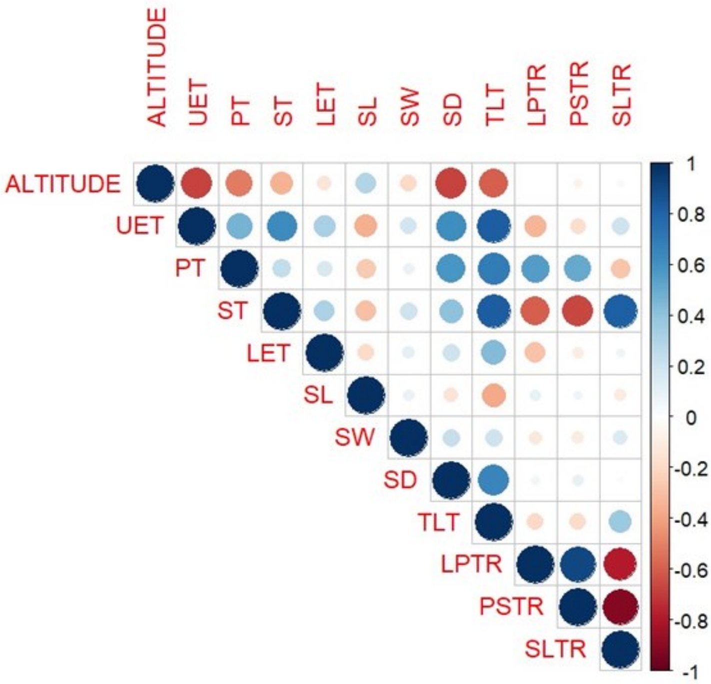


Fig. 3. Correlation among the anatomical tissue parameters. UET: upper epidermis thickness, PT: palisade thickness; ST: sponge thickness; LET: lower epidermis thickness; SL: stomata length; SD: stomata density; SW: stomata width; TLT: total leaf thickness; LPTR: leaf thickness-palisade thickness ratio; PSTR: palisade thickness-sponge thickness ratio; SLTR: sponge thickness-leaf thickness ratio.

Table 1. Values of measured anatomical parameter (with the standard deviation value) of *Miconia crenata* leaves along different elevation: 715, 800, 900, and 1,000 m asl. Number of measurements for each individual: 10 measurements, total measurements: 40 measurements per elevation.

Anatomical parameter	Elevation (m asl)			
	715	800	900	1,000
Length of stomata (µm)	18.10 ± 1.17	19.08 ± 1.35	18.45 ± 1.43	19.58 ± 1.44
Width of stomata (µm)	16.32 ± 1.21	15.79 ± 1.19	16.25 ± 1.38	15.45 ± 1.01
Stomata density (∑stomata/mm^2)	506 ± 99	338 ± 67	332 ± 82	271 ± 46
Upper epidermis thickness (µm)	18.21 ± 2.31	11.54 ± 2.12	14.91 ± 2.29	8.59 ± 1.49
Lower epidermis thickness (µm)	10.59 ± 1.85	9.34 ± 1.28	11.17 ± 2.09	9.20 ± 1.47
Palisade thickness (µm)	32.36 ± 7.74	19.58 ± 1.86	14.91 ± 2.29	20.91 ± 1.83
Sponge thickness (µm)	30.09 ± 8.10	16.45 ± 2.39	27.91 ± 6.20	17.40 ± 3.56

The thickness of upper epidermis of *M. crenata* tend to decrease as the altitudinal increases (Fig. 3). Nevertheless, this pattern is not consistent (Table 1). A comparable trend was observed in lower epidermis, sponge and leaf thickness of *M. crenata*. Conversely, the thickness of the palisade of *M. crenata* decreased as altitude increase from 715 to 900 m asl, with corresponding thickness values of 32.36 µm, 19.58 µm, 14.91 µm. Then increasing at an altitude of 1,000 m asl (20.91 µm) (Table 1).

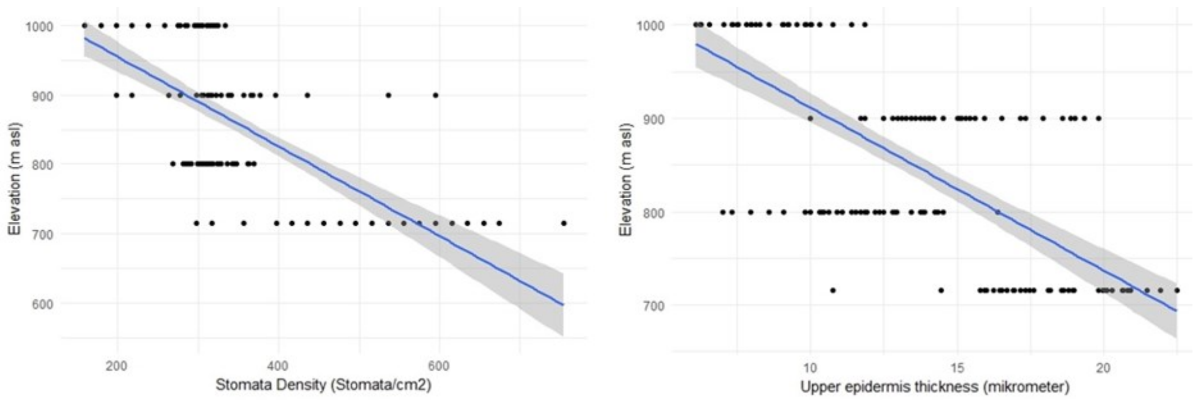
Leaf thickness of *M. crenata* is strongly correlated with the upper epidermis, sponge, and palisade, indicating that the majority of leaf thickness is contributed by the sponge and palisade thickness (Fig. 4). In addition, there is positive correlation between leaf thickness and stomata density, however it is not very strong. Similar findings were also achieved regarding the association between stomata density and upper epidermis thickness.

DISCUSSION

Miconia crenata is an exotic plant in MGPNP that has become invasive due to its highly successful dispersal technique and reproductive strategies, resulting in the high number of seed production. Invasive plants species employ a vegetative approach by adapting to many types of environments and rapidly developing their vegetative as a fast-growing species (van Kleunen *et al.*, 2010). In this study, we detected this vegetative adaptation due to its leaf anatomical variation along elevation. The value of stomatal density and leaf upper epidermis thickness of *M. crenata* were getting smaller along the increase of the habitat elevation.

The negative correlation of elevation and the stomata density was consistent with a relevant study by Putri *et al.* (2022) that suggested that the stomata density value of an exotic species *Bartlettina sordida* at MGPNP tends to get lower along the increase of altitude. The same results are found by Li *et al.* (2006) and Nautiyal & Purohit (1980). Stomata have the function of regulating the exchange of O_2 and CO_2, and water (Hetherington & Woodward, 2003; He & Liang, 2018; Lawson & Matthews, 2020). However, this finding contradicts the finding of Liu *et al.* (2020) who reported a positive correlation between stomatal density and elevation. At higher altitude, the availability of CO_2 and O_2 is generally reduced. Consequently, plants should enhance their stomatal density to optimize their CO_2 and O_2 intake. However, stomatal density has positively correlate with light intensity (Liu *et al.,* 2020). Hence, we speculate that the leaf of *M. crenata* at higher altitude are having smaller stomatal density because of potentially lower light intensity. This is due the fact that most of the examined specimens grew under the shade of forest canopies.

Yang *et al.* (2022) and Yang *et al.* (2023) have found that the upper and lower epidermis thickness tend to decrease as altitude increase. This reduction enhances the efficiency of gas exchange between leaves and the external environment. There was a negative correlation between the thickness of *M. crenata* palisade tissue and altitude. This finding is in concordance with previous studies conducted by Yang *et al.* (2022), Yang *et al* (2023), and Nautiyal & Purohit (1980) which stated that the palisade thickness tends to decrease as altitude decreases. According to their studies, the reduction of the palisade, sponge and leaf thick-



(A) (B)

Fig. 4 The linear regression model that indicate the significant negative correlation between elevation stomata density (A) and elevation and upper epidermis (B) of the *Miconia crenata* leaves. Number of samples are 160. The correlation coefficient between altitude and the density of the stomata and upper epidermis thickness are -0.39 (p-value = 7.07×10^{-9}) and -10.95 (p-value = 2.15×10^{-9}) respectively. The adjusted r square for the model is 0.56.

ness indicates a plant adaptation to drought stress and to increase CO_2 intake. However, Liu *et al.* (2020) and Li *et al.* (2006) discovered a contradictory result that suggested a positive correlation between palisade thickness and habitat elevation. Palisade is the leaf tissue that responsible for carrying out photosynthesis. Palisades are known as plastic tissue because of their adaptability to the environment. A thicker palisade tissues could be associated to enhanced photosynthetic efficiency and could be an indication of the amount of chloroplast.

However, this study discovered an abnormality in the leaf thickness and palisade of *M. crenata* at an altitude of 900 m alt. This anomaly may be caused by plant phenotypic plasticity factor. The flexibility of plant tissue is determined by environmental factors such as temperature, humidity, CO_2 content, and even wind (Nautiyal & Purohit, 1980; Jahdi *et al.*, 2020). These environmental factors are not the sole determinants of plant tissue and its plasticity. Therefore, any deviation in the examined individuals in this study may be impacted by one or several environmental factors that differ or fluctuate to some extent at each altitude.

According to the fundings of this study, the ability of *M. crenata* to adjust to different light conditions was relatively noticeable. This species was observed in several environmental conditions characterized by diverse levels of light intensity and shade. In the tropical forest context, *M. crenata* is recorded as an exotic species capable of thriving in the innermost area of the undisturbed tropical forest as a result of its adaptation (Waddell *et al.*, 2020). In this study, we did not collect light data on the parameter of light. However, considering the state of the sampling sites, the plots were located in close proximity or directly along the hiking trail road, exhibiting a similar trees canopies density and condition to some extent. Therefore, we assumed that there is negligible difference in the light condition among the sampling plots. We acknowledge that this assumption is a limitation of this study. Hence, further research is required for leaf anatomical variation of exotic invasive species in relation to various seasonal and environmental factors such as light intensity, pH, temperature, and humidity. Furthermore, it is necessary to compare the structure variation across different plant taxa and growth forms.

CONCLUSIONS

The adaptation of *M. crenata* leaves towards altitude in Gunung Gede-Pangrango National Park involves alterations in the stomata size, stomata density, and thickness of mesophyll tissue and leaves. The higher the altitude, the thinner of upper and lower epidermis, palisade, sponge and leaf of *M. crenata*. In higher altitudes, *M. crenata* exhibited lower stomatal density and longer stomatal size.

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