Exploration of wood species at Enggano Island:
Identification and fiber morphology measurements

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Abstract. The objectives of this exploration were to identify and characterize the lesser-known wood species in Enggano island, and to find the suitability especially for construction and sawn-timbers. Wood samples were taken by drilling the trees to obtain a pencil-like shape with a size of 20 cm in length and 0.5 cm in diameter. Identification and anatomical structure observation of wood samples were carried out according to the International Association of Wood Anatomist (IWA). Preparation of maceration for wood fiber dimension measurement followed the modified Franklin method. Physical properties of wood were investigated to obtain the specific gravity data. Absolute bending and compression strength, as well as the strength class were estimated through the specific gravity values based on Indonesian Forestry Classification. As many as 22 wood species have been collected, where nine of which were categorized as lesser-known wood species. Wood species at Enggano island which have potential as construction timber with strength class II were Ki Ahid (Intsia palembanica) and Kasai (Kingiodendron alternifolium); and that for sawn-timbers with strength class III were Kabaruk (Anriaris sp.) and Ki Ono (Combretocarpus rotundatus). From the fiber morphological measurements, it was indicated that the smaller the lumen diameter and the longer the fiber, the specific gravity of wood increased.

1. Introduction
In the period before 1985, Indonesia was a producer of various qualified tropical wood species on the world market. However, management and exploitation that did not pay attention to sustainability results in a decrease in the ability of natural forests to provide high-quality wood for raw materials of timber industries. Currently, wood production other than from natural forests that is 5 million m³, comes from plantation forests of 26.67 million m³ and community forests of 3.93 million m³ [1]. The production of primary industries includes sawn wood is 1.18 million m³, pulp 5.42 million tons, veneers 0.9 million m³, and plywood 3.2 million m³. Log production in 2017 came from Acacia (Acacia mangium 63.36%), Meranti (Shorea leprosula 10.57%), Sengon (Paraserianthes falcatoria
7.80%), Ekaipitus (Eucalyptus sp. 7.75%), mixed woods (5.09%), and others (5.43%) with a total production of 49.13 million m$^3$ [2]. From these data, it can be seen that Acacia wood from forest industrial plantations dominates the wood supply, which amounted to 31.13 million m$^3$ that mostly for pulp and paper industries.

To overcome the limited raw materials from commercial wood species for sawn timber, veneers and plywood, it is necessary to diversify the sources of wood raw materials by developing and utilizing lesser-known wood species or by exploring the potential wood species from small or bordered islands in Indonesia. Besides the wood species that have been developed into forest industrial plantations before, such as Acacia, Ekaipitus, Gmelina (Gmelina arborea), and Pinus (Pinus merkusii) which are generally used for pulp and paper raw material [3], it is estimated that there are still many lesser-known wood species that have the potential to be used as raw materials for the timber industries and various wood-based products according to their characteristics. Based on the Forest Inventory and Administration Agency, Ministry of Forestry, there are 3,124 wood species consisting of commercial, non-commercial, unknown, and cultivated wood [4]. According to the classification in the Prosea book, 51 genera belong to major commercial timbers, 62 genera of minor commercial timbers, and 309 genera of lesser-known timbers in South-East Asia [5-7], whereas the four volumes of Indonesian Wood Atlas only describe the basic properties of 122 genera of Indonesian woods [8-11].

Assuming the demand for wood continues to increase from year to year, there is an opportunity for forest industrial plantations to play a greater role in providing raw material for wood [12]. The development of lesser-known wood species through forest industrial plantations has the potential to provide a portion of the wood demand for the substitution of raw materials that has been explored from natural forests.

Intensive research on lesser-known and fast growing wood species have been started since 1990, including Gmelina [13,14], Mindi (Melia azedarach L.) [15,16], Gadog (Bischofia javanica Blume) [17], and Cengkeh (Syzygium aromaticum L.) [18]. Wood species with strength class II and have a high ratio of strength to weight can be utilized for construction timbers [19]. Factors that need to be considered if the wood is to be used as construction timbers are (1) specific gravity, (2) dimensional stability, (3) strength, (4) natural durability, and (5) workability. The trees also should have good morphological characteristics, namely (7) straight stem and (8) high free branching. If the potential wood species are going to be developed for forest industrial plantation, factors that need to be taken into account are (9) silvicultural, (10) growth rate, (11) disease resistance, and (12) utilization prospects.

Since 2015, Indonesian Institute of Sciences (LIPI) has conducted exploration activities to the outer islands in Indonesia. Enggano is a small island located in the Indonesian Ocean, the southwest of Bengkulu Sumatra island. Most of the land is still covered by forests. Enggano island still has a lot of potential wood and non-timber forest products to be explored. Based on its function, the forest area of Enggano Island is consisting of limited production forests, protected forests, nature reserves, and hunting parks. The forest ecosystems are lowland forest, swamp forest, mangrove forest, and coastal forest. The topography of the forest area varies from flat to steep with a height of 0~220 m above sea level. The dominant species in the lowland forests are the Dipterocarpaceae, Sapindaceae, and Myrtaceae; in the swamp forest are the Palmae and swamp grass; in the mangrove forests are Rhizophoraceae and Soneratiaceae; while in the coastal forests are Malvaceae and Guttiferae.

The purpose of this exploration activity was to identify and characterize the wood species found in Enggano island, and to provide recommendation which wood species are potential for construction and sawn-timbers according to the wood properties. The selected species could be considered to be planted widely through forest industrial plantation as an alternative of commercial trade wood species in providing various raw materials of wood-based products.

2. Materials and methods

2.1. Wood test sampling
The wood samples were carried out from the forests which were expected to represent lowland and coastal forest ecosystem. The wood sampling for identification and characterization was conducted
based on morphological criteria of trees that have a diameter of 40 cm or above, 10 m or above for free branches height, and have straight/cylindrical stems, with the expectation of high wood volume and quality. The wood sample was taken by drilling a tree using a drill tool at a height of 1.3 m to obtain a pencil-like shape with a size of 20 cm in length and 0.5 cm in diameter for the basic property measurements (anatomical and physical properties). In addition, several leaves and wood chips were taken for wood species verification through the herbarium specimens and anatomical structure observation.

2.2. Observation of anatomical structure and identification
The microscopic structure of the cross section for anatomical observations was carried out on the incision of wood sample with a thickness of 40 µm using a sliding microtome. The dehydration was conducted using 30%, 50%, 70%, 96%, and absolute alcohol, respectively, followed by soaking the sliced wood sample in carboxylol and toluene, and then placing them on an object glass. Identification and observation of wood anatomical structures followed the International Association of Wood Anatomists [20].

2.3. Fiber morphological measurement
Fiber maceration of wood samples were prepared by using modified Franklin method [21]. The samples were heated slowly at 40–60°C in the solution of 1:1 Acetic Acid and Hydrogen Peroxide (H₂O₂) in a boiling water bath for 12 hours or more to produce milky white to almost transparent whips and satisfactory separation of cells. Then the separated cells were washed with water to remove residual acid and H₂O₂, and stained with Safranin. Fiber dimensions, i.e., fiber length were observed and measured under a microscope.

2.4. Specific gravity measurement
After cutting to 1 cm in length, the wood samples were weighed by immersing them into water and measured in length and diameter to get the initial weight (Wo) and volume (Vo) in fresh condition. Then the wood samples were dried at 60°C for about three days to get an oven-dry weight (Wod). The specific gravity of wood was calculated by the formula Wod/Vo [22].

2.5. Estimation of mechanical properties and testings
The mechanical properties values (absolute bending strength and absolute compression strength), as well as the strength class were estimated through their specific gravity values based on the Indonesian Forestry Classification in Table 1 [23].

| Strength class | Specific gravity | Absolute bending strength (kgf/cm²) | Absolute compression strength (kgf/cm²) |
|----------------|-----------------|-----------------------------------|----------------------------------------|
| I              | over 0.90       | over 1100                          | over 650                               |
| II             | 0.60 to 0.90    | 725 to 1100                        | 425 to 650                             |
| III            | 0.40 to 0.60    | 500 to 725                         | 300 to 425                             |
| IV             | 0.30 to 0.40    | 360 to 500                         | 215 to 300                             |
| V              | under 0.30      | under 360                          | under 215                              |

Especially for four wood species that have generally been used by the community as construction and sawn-timbers, namely Merbau (Intsia bijuga), Nehek (Dillenia excelsa), Ketaping (Terminalia catappa), and Apua (Lagerstroemia floribunda), the mechanical properties were tested to determine the Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) based on British Standard (BS) 373-1957 [24]. A wood sample sized of 30 x 2 x 2 cm was loaded in the middle of a span and the maximum load was recorded until the wood sample was damaged. MOR and MOE values were calculated using the formula: MOR (kgf/cm²) = [(3PL) / (2bh²)], and MOE (kgf/cm²) = [(ΔPL³) / (4Δybh⁵)], where: P = load (kgf), ΔP = load change (kgf), L = span distance (cm), Δy = deflection (cm), b = sample width (cm), h = sample thickness (cm), l = sample length (cm).
3. Results and discussion

3.1. Identification and classification

As much as 22 wood species have been collected (Table 2), consisting of one species of strength class I, three species of strength class II, 13 species of strength class III, and five species of strength class IV. The strength classification was based on the specific gravity (Table 1). Ironwood (*Eusideroxylon zwageri*) had a strength class I, although it was unable to obtain the sample because the drill tool cannot penetrate the stem.

**Table 2. Wood species from an exploration in Enggano island.**

| No. | Local names | Botanical names | Specific gravity | Strength class | Commercial classes** | Fiber length* (μm) | Lumen diameter* (μm) |
|-----|-------------|-----------------|------------------|---------------|----------------------|-------------------|---------------------|
| 1   | Kayu Besi   | *Eusideroxylon Zwageri* | 0.71             | I             | Major                | 1260              | 21.58               |
| 2   | Ki Ahid     | *Intsia palembanica*  | 0.69             | II            | Lesser-known         | 1079              | 17.25               |
| 3   | Merbau      | *Intsia bijuga*     | 0.57             | II            | Lesser-known         | 1273              | 14.35               |
| 4   | Kasai       | *Kingiodendron alternifolium* | 0.56       | II | Lesser-known         | 1200              | 17.30               |
| 5   | Kempas      | *Koompassia malaccensis* | 0.51             | III           | Major                | 2009              | 23.88               |
| 6   | Nehek/ Simpur Terap | *Dillenia excelsa* | 0.56           | III           | Minor                | 1210              | 17.79               |
| 7   | Jati        | *Tectona grandis*   | 0.55             | III           | Major                | 1607              | 21.58               |
| 8   | Pakarot/ Medang | *Endiandra macrophylla* | 0.52            | III           | Major                | 1630              | 21.38               |
| 10  | Umih        | *Un-identified*     | 0.52             | III           | Lesser-known         | 1360              | 21.38               |
| 11  | Kabaruk     | *Antiris toxicaria* | 0.51             | III           | Lesser-known         | 1204              | 13.98               |
| 12  | Ki Oka/ Kelat | *Timonius sp.*    | 0.51             | III           | Minor                | 1962              | 16.56               |
| 13  | Apua        | *Lagerstroemia floribunda* | 0.50             | III           | Major                | 1435              | 17.50               |
| 14  | Ketaping/ Ketapang | *Terminalia catappa* | 0.50            | III           | Minor                | 1212              | 17.85               |
| 15  | Ehei/Dao    | *Dracomontemon dao* | 0.44             | III           | Minor                | 1031              | 17.26               |
| 16  | Ki Ono      | *Combretocarpus rotundatus* | 0.44         | III           | Lesser-known         | 1579              | 17.06               |
| 17  | Randu       | *Ceiba pentandra*   | 0.44             | III           | Lesser-known         | 1312              | 29.88               |
| 18  | Rengas      | *Gluta renghas*     | 0.31             | IV            | Minor                | 1316              | 29.88               |
| 19  | Pupua/ Amberoi | *Pterocymbium tinctorum* | 0.31      | IV            | Minor                | 1474              | 25.72               |
| 20  | Purut       | *Parartocarpus venosa* | 0.39             | IV            | Lesser-known         | 1553              | 29.36               |
| 21  | Kenanga     | *Cananga odorata*   | 0.31             | IV            | Lesser-known         | 1209              | 25.27               |

* [25]; ** [5-7].

The wood species were also grouped by commercial class into Major Timber, Minor Timber and Lesser-known Timber [5-7]. From the commercial classification, there were nine lesser known wood species, namely Ki Ahid (*Intsia palembanica*) and Kasai (*Kingiodendron alternifolium*) with strength...
class II; Umih, Kabaruk (*Antiaris toxicaria*), Ki Ono (*Combretocarpus rotundatus*), and Randu (*Ceiba pentandra*) with strength class III; and Purut (*Parartocarpus venenos*a), Kenanga (*Cananga odorata*), and Bayur (*Pterospermum javanicum*) with strength class IV. The trade names, scientific names, families, distribution, commercial classes,utilizations, general characteristics, and the basic properties of the woods are presented. These data were obtained from the identification, characterization and some literatures [5-10]. The conservation status based on International Union for Conservation of Natures’s Red List of Threatened Species (IUCN) Version 2020-1 of each species are provided for commercially consideration.

3.2. Fiber morphology

From the fiber morphology measurements of 17 wood species (Table 2), the wood species with the largest lumen diameter was Rengas (*Gluta renghas*) which was 29.88 µm and the smallest was Kabaruk (*Antiaris toxicaria*) which was 13.98 µm. The length of fibers ranged between 1031–2009 µm. The wood species that had long fibers (1600–2200 µm) according to the Indonesian Forestry Classification [23] were Nehek (*Dillenia excelsa*), Pakaror (*Endiandra macrophylla*) and Kioka (*Syzygium* sp.), while other wood species were classified into medium category (900~1600 µm). The wood species that had the longest fiber was Nehek (*Dillenia excelsa*, 2000 µm), and the shortest was Ehei/Dao (*Dracontomelon dao* 1031 µm) [25].

![Figure 1](image_url)

**Figure 1.** Relationships between fiber lumen diameter (left) and fiber length (right) with specific gravity.

Figure 1 shows the relationships between fiber lumen diameter (left) and fiber length (right) with specific gravity. From the Figure, it was indicated that the smaller the lumen diameter and the longer the fiber, the specific gravity of wood increased.

3.3. Mechanical properties

MOR and MOE values of four wood species that have generally been utilized by the community as construction and sawn timbers are shown in Table 3.

Merbau wood (*Intsia bijuga*) was included in strength class II and generally used for bridge construction. Likewise, Nehek wood (*Dillenia excelsa*) was used for lightweight construction purposes. Whereas Ketaping wood (*Terminalia catappa*) and Apua (*Lagerstroemia floribunda*) were widely used for sawn-timber.
Table 3. MOR and MOE values of four wood species from Enggano island that have been commonly utilized by local community.

| Wood species                      | MOR (kgf/cm²) | MOE (kgf/cm²) |
|-----------------------------------|---------------|---------------|
| Merbau (*Intsia bijuga*)          | 1101.24       | 128614.33     |
| Nehek (*Dillenia excelsa*)        | 828.30        | 99291.33      |
| Ketaping/Ketapang (*Terminalia catappa*) | 581.32    | 58213.43      |
| Apua (*Lagerstroemia floribunda*) | 551.30        | 93343.10      |

The analysis of anatomical, physical, and mechanical properties of 22 wood species found in Enggano island provided details description of wood species. Additional information of basic properties from literatures completed with habitus and macroscopic images will allow appropriate utilization and development of the wood species. The details of wood description are presented completed with the pictures of the trees and/or macroscopic images (Figure 2-4).

1. Kayu Besi (Figure 2A)
   - Trade name: Ulin
   - Scientific name: *Eusideroxylon zwageri*
   - Family: Lauraceae
   - Distribution: West Sumatra, East Sumatra, Bangka, Belitung, Kalimantan, and the Sulu Islands
   - Commercial class: major timber
   - Uses: heavy construction, poles, docks, ships, dams, bridges, masts, and traditional houses
   - General characteristics: heavy wood weight; wood terrace yellowish brown or reddish brown; sapwood dark yellow; wood grain straight and sometimes combined
   - Basic properties: specific gravity 1.04; strength class I; durability class I
   - Conservation status (IUCN): Vulnerable [26]

2. Ki Ahid (Figure 2B)
   - Trade name: Merbau
   - Scientific name: *Intsia palembanica*
   - Family: Caesalpiniaceae
   - Distribution: Tanzania, Madagascar, India, Myanmar, Malesia, Australia and Polynesia
   - Commercial class: lesser known
   - Uses: sawn wood
   - General characteristics: heavy, hard, the heartwood is light brown, orange-brown to dark red-brown, darkening on exposure, sharply differentiated from the lighter sapwood, usually without lustre, but light colored wood sometimes slightly lustrous and with stripe Figure on radial surface. The grain is straight, interlocked to wavy, the texture moderately coarse and coarse but even
   - Basic properties: specific gravity 0.71; strength class II
   - Conservation status (IUCN): Vulnerable [27]

3. Merbau (Figure 2C)
   - Trade name: Merbau
   - Scientific name: *Intsia bijuga* (colebr.) O. Kuntze
   - Family: Caesalpiniaceae
Distribution: Tanzania, Madagascar, India, Myanmar, Malesia, Australia and Polynesia
Commercial class: major timber
Use: window, door, frame, floor, furniture, panel, stairs, truck body, lathe, pole, musical instrument, carving, and bridge
General characteristics: heavy and hard; brown patio wood; pale yellow sapwood; straight fiber
Basic properties: specific gravity 0.70; strength class II; durability class I-III
Conservation status (IUCN): Vulnerable [27]

4. Kasai (Figure 2D)
Trading name: Kasai
Scientific name: Kingiodendron alternifolium
Family: Caesalpinaceae
Distribution: India, the Philippines, New Guinea, New Britain, Solomon Island and Fiji
Commercial class: lesser known
Uses: furniture, floors, doors, roofs and walls
General characteristics: medium weight; reddish brown patio wood; yellowish brown sapwood; chime fiber
Basic properties: specific gravity 0.69; strength class II; durability class V
Conservation status (IUCN): Endangered (Kingiodendron pinnatum) [28], Least Concern (Kingiodendron platycarpum) [29]

5. Kempas (Figure 2E)
Trading name: Kempas
Scientific name: Koompassia malaccensis
Family: Caesalpiniaceae
Distribution: Vietnam, Cambodia, Andaman Island, Thailand, Solomon Island and Australia
Commercial class: major timber
Uses: lightweight construction, flooring, molding, panel boards, joints, furniture, veneers, plywood, pallets, boat construction, surfboards, poles, bridges, and musical instruments
General characteristics: medium weight; patio wood brownish orange, brownish pink, or brownish red; brownish yellow sapwood with a hint of pink; fiber chime and wavy.
Basic properties: specific gravity 0.57; strength class III; durability class II-IV.
Conservation status (IUCN): Vulnerable (Koompassia grandiflora) [30], (Koompassia excelsa) [31], (Koompassia malaccensis) [32]

6. Nehek (Figure 2F)
Trading name: Simpur
Scientific name: Dillenia excelsa (Jack) Gilg
Family: Dilleniaceae
Distribution: Thailand, Malaysia, Sumatra, Bangka, West Java, Kalimantan and the Philippines
Commercial class: minor timber
Uses: construction, beams, joints, roof frames, sills, stairs, floors, decorative wall panels, furniture, molding, boats,
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General characteristics: moderate to severe; reddish brown patio wood; paler colored wood; chime fibers sometimes straight
Basic properties: specific gravity 0.56; strength class III
Conservation status (IUCN): No information

Figure 2. Tree of Kayu Besi (*Eusideroxylon zwageri*) (A); Tree (left) and anatomical structure (right) of Ki Ahid (*Intsia palembanica*) (B); Tree (left) and anatomical structure (right) of Merbau (*Intsia bijuga* (colebr.) O. Kuntze) (C); Tree (left and anatomical structure (right) of Kasai (*Kingiodendron alternifolium*) (D); Anatomical structure of Kempas (*Koompassia malaccensis*) (E); Tree (left) and anatomical structure (right) of Nehek (*Dillenia excelsa* (Jack) Gilg) (F).
7. Terap (Figure 3A)

| Trade name  | Terap |
|-------------|-------|
| Scientific name | Artocarpus lanceifolius |
| Family       | Moraceae |
| Distribution | Thailand, Malaysia, Sumatra, Bangka, Riau and Lingga Islands, and Kalimantan |
| Commercial class | minor timber |
| Uses         | lightweight construction, boxes and crates, wooden pallets, veneers, furniture, joints, and panels |
| General characteristics | light weight; wood patio pale yellow or yellowish brown; not clearly separated from sapwood; chime fiber |
| Basic properties | specific gravity 0.56; strength class III |
| Conservation status (IUCN) | No information |

8. Jati (Figure 3B)

| Trade name  | Teak |
|-------------|------|
| Scientific name | Tectona grandis L.f. |
| Family       | Verbenaceae |
| Distribution | India, Myanmar, Thailand, Laos and Java |
| Commercial class | major timber |
| Uses         | ship floor, boat, house floor, railroad tracks, furniture, bridges, connections, building poles, fences, walls, boxes, musical instruments, toys, train construction, veneers, decorative plywood, charcoal, and firewood. |
| General characteristics | medium weight; patio woods golden brown, golden dark brown; sapwood white, yellowish white to yellowish brown; straight or wavy fibers, sometimes combined |
| Basic properties | specific gravity 0.55; strength class III; durability class II |
| Conservation status (IUCN) | No information |

9. Pakaror (Figure 3C)

| Trade name  | Medang |
|-------------|--------|
| Scientific name | Endiandra macrophylla |
| Family       | Lauraceae |
| Distribution | Thailand, Malaysia, Sumatra, and Kalimantan |
| Commercial class | lesser known |
| Uses         | floor, panel, roof, interior, joints, decking, musical instruments, crates, boxes, toys, lathe, lighters, fiberboard, particle board, plywood, and veneer |
| General characteristics | medium weight; patio woods reddish brown, dark red, or reddish brown; sapwood is not too different from patio wood; chime and wavy fibers |
| Basic properties | specific gravity 0.52; strength class III |
| Conservation status (IUCN) | Least Concern for majority of Endiandra species; with the exception for E. holttumii (Endangered), E. lecardii (Vulnerable), E. wrayi (Near Threatened), and E. scrobiculata (Critically Endangered) [33] |

10. Umih

| Trade name  | Un-identified |
|-------------|---------------|
| Scientific name | Un-identified |
| Family       | Un-identified |
| Distribution | Un-identified |
Commercial class: lesser known
Uses: lightweight construction, floors, sills, roofs, interior decoration, furniture, toys, lathe, boxes, ships and boats, connections, plywood, veneers, particle boards, fiberboard, and pulp
General characteristics: light weight; yellowish brown patio wood with a greenish pattern; sapwood is paler and yellower; chime fiber
Basic properties: specific gravity 0.52; strength class III

11. Kabaruk (Figure 3D)
Trade name: Kabaruk
Scientific name: Antiaris toxicaria
Family: Moraceae
Distribution: West Africa, Sri Lanka, India, Indo-China, Southern China, Thailand, Malesian Region, Pacific and North Australia
Commercial class: lesser known
Uses: lightweight construction, interior, furniture, molding, paneling, flooring, plywood, veneers, and block boards.
General characteristics: light weight; wood terrace white or pale yellow; colored sapwood cannot be distinguished; chime fiber
Basic properties: specific gravity 0.51; strength class III
Conservation status (IUCN): No information

12. Ki Oka (Figure 3E)
Trade name: Kelat
Scientific name: Timonius sp.
Family: Rubiaceae
Distribution: Indo-China, Malaysia, Java, Kalimantan, the Philippines and Papua New Guinea
Commercial class: minor timber
Uses: construction, furniture, floors, ships, bridges, equipment, fiberboard, veneers, plywood, charcoal and firewood
General characteristics: moderate to severe; patio wood grayish brown, golden brown, or reddish brown to reddish brown or purplish brown; paler colored wood; fiber chime or less regular
Basic properties: specific gravity 0.51; strength class III; durability class III
Conservation status (IUCN): From Least Concern (Timonius timon, T. pubistipulus and T. flavescens); Vulnerable (T. celemntis) to Critically Endangered (T. jambosella) [34]

13. Apua (Figure 3F)
Trade name: Bungur
Scientific name: Lagerstroemia floribunda
Family: Lythraceae
Distribution: Thailand, Malaysia, Sumatra, Riau Islands, Bangka, Belitung and Kalimantan
Commercial class: major timber
Uses: pallets, frames, tool handles, marine construction, parquet, panel board, and furniture
General characteristics: medium weight; wood patio reddish orange or brownish
red with many brownish yellow stripes; clearly separated with sapwood which is whitish brown and whitish yellow; fiber chime and wavy

Basic properties: specific gravity 0.50; strength class III; durability class III-IV

Conservation status (IUCN): From Least Concern (*Lagerstromia excels* and *L. indica*); Vulnerable (*L. anisoptera* and *L. intermedia*), and Endangered (*L. langkawiensis* and *L. minuticarpa*) [35]

14. Ketaping (Figure 3G)

**Trade name**: Ketapang

**Scientific name**: *Terminalia catappa* L.

**Family**: Combretaceae

**Distribution**: India, Indo-China, Thailand, Malesia, Australia and Polynesia

**Commercial class**: minor timber

**Uses**: lightweight construction, sills, crates, molding, beams, roof frames, floors, furniture, trains, agricultural tools, tool handles, lathe, boats, pile foundations, veneers, and plywood

**General characteristics**: mild to moderate weight; patio wood brown, light brown, reddish brown, light yellow, and yellowish brown; pig wood is a little paler; straight fiber to chime

**Basic properties**: specific gravity 0.50; strength class III; durability class IV

**Conservation status (IUCN)**: No information

15. Ehei (Figure 3H)

**Trade name**: Dao

**Scientific name**: *Dracontomelon dao* (Burs.)

**Family**: Anacardiaceae

**Distribution**: India, Myanmar, Thailand, Cambodia, South China, the Malesia Region, and Solomon Island

**Commercial class**: minor timber

**Uses**: furniture, joints, decorative veneers, plywood, panels, molding, floors, lightweight construction, ships, and carvings

**General characteristics**: mild to moderate weight; wood terrace grayish and greenish yellow; paler colored wood; straight or chime fibers

**Basic properties**: specific gravity 0.44; strength class III; durability class IV

**Conservation status (IUCN)**: From Vulnerable (*D. lenticulatum*), Endangered (*D. costatum*), to Critically Endangered (*Dracontomelon macrocarpum*) [36]

16. Ki Ono (Ki Ona) (Figure 4A)

**Trade name**: Tumih

**Scientific name**: *Combretocarpus rotundatus*

**Family**: Rhizophoraceae

**Distribution**: Sumatra (Riau Archipelago, Bangka and Belitong), Borneo, Sarawak, Brunei, Peninsular Malaysia

**Commercial class**: lesser known

**Uses**: heavy interior construction and railway sleepers, temporary construction exposed to the weather, furniture, flooring,
16. Randu (Figure 4B)

Trade name: Randu
Scientific name: *Ceiba pentandra* (L.) Gaertn.
Family: Malvaceae
Distribution: medium weight hardwood; the heartwood is reddish-brown and generally distinct from the grey-white sapwood which turns grey-brown upon exposure; texture coarse and uneven; tangential and radial surfaces exhibit an attractive silver grain.

Conservation status (IUCN): Vulnerable (*Combretocarpus rotundatus*)

17. Rengas (Figure 4C)

Trade name: Rengas
Scientific name: *Gluta renghas* L.
Family: Anacardiaceae
Distribution: Malaysia, Sumatra, Java, Kalimantan, Sulawesi, Maluku, Myanmar and Thailand
Commercial class: lesser known
Uses: joints, furniture, panels, floors, rotary veneers, plywood, lathe, poles, ships, and molding

Conservation status (IUCN): Least Concern [32]

18. Pupua (Figure 4D)

Trade name: Amberoii
Scientific name: *Pterocymbium tinctorum*
Family: Sterculiaceae
Distribution: Myanmar, Nicobar and Andaman Islands, Indo-China, Thailand, Malesian Region and Fiji
Commercial class: minor timber
Uses: veneer, plywood, molding, furniture, boats and pulp

Conservation status (IUCN): Least Concern (*Pterocymbium tinctorum*) and Critically Endangered (*Pterocymbium oceanicum*) [37]
Figure 3. Tree (left) and anatomical structure (right) of Terap (*Artocarpus lanceifolius*) (A); Tree (left) and anatomical structure (right) of Jati (*Tectona grandis* L.f.) (B); Tree (left) and anatomical structure (right) of Pakaror (*Endiandra macrophylla*) (C); Tree (left) and anatomical structure (right) of Kabaruk (*Antiaris toxicaria*) (D); Anatomical structure of Ki Oka (*Timonius* sp.) (E); Tree (left) and anatomical structure (right) of Apua (*Lagerstroemia floribunda*) (F); Tree of Ketaping (*Terminalia catappa* L.) (G); Tree (left) and anatomical structure (right) of Ehei (*Dracontomelon dao* (Burs.)) (H).
Figure 4. Tree (left) and anatomical structure (right) of Ki Ono (*Combretocarpus rotundatus*) (A); Tree of Randu (*Ceiba pentandra* (L.) Gaertn.) (B); Anatomical structure of Rengas (*Gluta renghas* L.) (C); Anatomical structure of Pupua (*Pterocymbium tinctorium*) (D); Tree (left) and anatomical structure (right) of Purut (*Parartocarpus venenosa*) (E); Tree (left) and anatomical structure (right) of Kenanga (*Cananga odorata*) (F); Tree (left) and anatomical structure (right) of Bayur (*Pterospermum javanicum* Jungh.) (G).

20. Purut (Figure 4E)

| Description                    | Details                                      |
|--------------------------------|----------------------------------------------|
| Trade name                     | Purut                                        |
| Scientific name                | *Parartocarpus venenosa*                     |
| Family                         | Moraceae                                     |
| Distribution                   | Thailand, the Malesian Region, and Solomon Island |
| Commercial class               | lesser known                                 |
| Uses                           | lightweight construction, flooring, furniture, sills, block boards, particle boards, plywood, cast boards, crates and pallets, panels, boats, vehicle bodies, sports equipment, musical instruments, lathe, toys, and molds |
| General characteristics        | mild to moderate weight; wood terrace yellowish white to grayish white; not clearly separated from sapwood; straight fiber slightly chime |
21. Kenanga (Figure 4F)

- **Trading name**: Boxwood
- **Scientific name**: *Cananga odorata* (Lam.) Hook.f. & Thomson
- **Family**: Annonaceae
- **Distribution**: India, Fiji, Australia, the Philippines, and Malaya
- **Commercial class**: lesser known
- **Uses**: light construction, molding, box, carving, pulp and firewood
- **General characteristics**: white-gray patio wood; not clearly separated from sapwood; straight and wavy fibers
- **Basic properties**: specific gravity 0.36; strength class IV; durability class V
- **Conservation status (IUCN)**: Least Concern [38]

22. Bayur (Figure 4G)

- **Trade name**: Bayur
- **Scientific name**: *Pterospermum javanicum* Jungh.
- **Family**: Sterculiaceae
- **Distribution**: Myanmar, Malaysia, Sumatra, Java, Kalimantan, and Maluku
- **Commercial class**: lesser known
- **Uses**: joints, flooring, furniture, walls, tool handles, plywood, ships, bridges, boards, roof frames and pulp
- **General characteristics**: mild to moderate weight; patio wood pale brown to reddish brown with a purple hue; not clearly separated from sapwood; straight fiber slightly chime
- **Basic properties**: specific gravity 0.31; strength class IV; durable class IV-V
- **Conservation status (IUCN)**: No information

### 4. Conclusions

According to the wood properties, from the 22 wood species found in Enggano Island, two lesser known wood species had the potential as construction timbers, namely Ki Ahid (*Intsia palembanica*) and Kasai (*Kingiodendron alternifolium*), which belong to the strength class II. Four lesser-known wood species namely Umih, Kabaruk (*Antiaris toxicaria*), Ki Ono (*Combretocarpus rotundatus*), and Randu (*Ceiba pentandra*) which belong to the strong class III, were potential for sawn-timber. Due to the conservation status, the information regarding *Intsia palembanica* (Vulnerable), *Kingiodendron alternifolium* (Least Concern to Endangered), and *Combretocarpus rotundatus* (Vulnerable), should be carefully disseminated to the public. To support the utilization of those potential timber, the information regarding the cultivation is needed.

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