

Adaptation and local knowledge of the Marind Anim Tribes in the utilization of Paperbark trees (*Melaleuca leucadendron*) in Merauke, South Papua, Indonesia

SUHARNO¹✉, AKHMAD KADIR²

¹Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Cenderawasih. Jl. Kamp. Wolker Perumnas III, Yabansai, Heram, Jayapura 99224, Papua, Indonesia. Tel./fax.: +62-967-572-118, ✉email: harn774.uncen@gmail.com

²Department of Anthropology, Faculty of Social and Political Sciences, Universitas Cenderawasih. Jl. Kamp. Wolker Perumnas III, Yabansai, Heram, Jayapura 99224, Papua, Indonesia

Manuscript received: 10 October 2023. Revision accepted: 29 November 2023.

Abstract. *Suharno, Kadir A. 2023. Adaptation and local knowledge of the Marind Anim Tribes in the utilization of Paperbark trees (Melaleuca leucadendron) in Merauke, South Papua, Indonesia. Biodiversitas 24: 6323-6331.* Papuan rainforests are one of the most immensely diverse in the world. Such rich biodiversity provides a source of livelihood for the inland communities in Merauke, South Papua Province. For example, Paperbark trees (*Melaleuca leucadendron*) or *kayu bus* in the local language, which grow dominantly in lowland areas, are essential for the lives of the local inhabitants, the Marind Anim tribe. This research aims to elaborate on the use of Paperbark trees (*M. leucadendron*) by the Marind Anim tribe in their daily lives. Data were collected from surveys, interviews, and field observations. The interviews were conducted in multiple locations: Merauke, Sota, Muting, Semangga, and Tanah Miring. The results show that all members of the Marind Anim tribe (100%) depend on Paperbark for their livelihood, especially for the need for housing. The community has been using Paperbark trunks for house frames (92.31%), either unprocessed or in the forms of wooden blocks (5 x 5, 5 x 10, 10 x 10 cm) and boards (2 x 20 cm). They also utilize the wood for firewood. Other tribe members, i.e., the residents of the Wasur National Park, extract essential oils from Paperbark leaves. This utilization receives assistance and support from the area manager of the national park. Other than that, the community also utilizes the bark for house roofs, mats for crops, and firewood. In brief, the community's dependence on Paperbark trees is high because, other than being versatile, they are endemic to the lowland areas of Merauke, dominating other tree species. The findings suggest the importance of establishing a sound management system for the utilization of Paperbark trees to maintain sustainability in meeting the needs of surrounding communities.

Keywords: Biodiversity, lowland forest, *M. leucadendron*, Merauke, Paperbark trees

INTRODUCTION

Communities worldwide depend on nature and fulfill their primary needs from the environment (Bennett et al. 2015; Fedele et al. 2021). The conditions of environmental resources today are greatly influenced by the communities' sustainable utilization policies (Bonnedahl et al. 2022; WWF 2022; Børresen et al. 2023). Human interactions in everyday life are closely linked to the existence of wild species, which help shape individual and cultural meanings, values, and norms related to resources and landscapes (Roe and Booker 2019; Mekonen 2020; Allan et al. 2022). However, population growth and improving well-being often lead to the exploitation of natural resources, which drives global warming, loss of biodiversity, and other ecological damages (Ceballos et al. 2015; Bonnedahl et al. 2022). This exploitation is driven by limited sources from domestication and worsened by the lack of environmental improvement efforts (Bonnedahl et al. 2022; Makhubele et al. 2022). On Papua Island, most people depend on nature for their livelihoods, especially sources of shelter and food (Kadir et al. 2022).

Forests in Papua are rich in biodiversity, both the flora and fauna. For example, the Paperbark tree (*Melaleuca*

leucadendron) of the Myrtaceae family is one of the endemic plants in the lowland areas of southern Papua (Yarman and Damayanti 2012; Tanjung et al. 2020). The locals call it *kayu bus*. Besides Papua, it grows in Maluku, East Nusa Tenggara, Southeast Sulawesi, Bali, and Java (Helfiansah et al. 2013). Paperbark trees are latent with potential, including the leaves, which can produce essential oil (Pujiarti et al. 2011). Paperbark tree oil can be used as herbal remedies, such as antiseptics, antispasmodics, antineuralgics, and antirheumatics, and as a material in cosmetics manufacturing. Studies have also demonstrated its efficacy as antibacterial, antiviral, anti-termite, and antifungal (Pujiarti et al. 2011; Gatenby and Townley 2014; Patramurti et al. 2020; Isah et al. 2023). It can be used as an additional sunscreen material to reduce sunburn risk and prevent skin diseases (Silva et al. 2020).

In Merauke, Papua, the Paperbark trees are widely used by the community because the endemic plant is easily obtainable from their surrounding environment. Aside from being used for pillars in residential buildings and bridge floors, Paperbark timber can also be used as materials for wood products, firewood, and charcoal (Purwanto 2015). Meanwhile, the distillation of Paperbark leaves can produce an essential oil with up to 50-65% eucalyptol or cineole

(Patramurti et al. 2022). The Paperbark trees, as the Marind Anim tribe community defines, refer to the endemic forest plants in Merauke, i.e., *Melaleuca*. These dominating species include *Melaleuca* sp., *Lophostemon lactifluus*, *Xanthostemon* sp., *Acacia leptocarpa*, *Asteromyrtus symphiocarpa*, *Eucalyptus* sp. (Yarman and Damayanti 2012).

Marind Anim tribe is the largest tribe in Merauke, inhabiting the lowland areas of Papua (Kadir et al. 2020), from the Muli Strait (Marianne Strait) to the border of Papua New Guinea (PNG). This tribe still depends on nature for its livelihood (Suharno et al. 2016; Kadir et al. 2020; Kadir et al. 2022). It should be noted that relationships between humans and nature in Marind Anim are not only for livelihood needs. The ecosystems are cultural, so there is a relation with the indigenous group's identity, norms, and values (Deutsch 2014; Sangha et al. 2015; Viscogliosi et al. 2020). For example, the Marind Anim tribe still believes in *totems* as part of their social life and beliefs; *totems* can be animals, plants, or natural figures that spiritually represent a group related to the tribe. This belief is vital in protecting and maintaining flora, fauna, or natural figures, which can indirectly become an asset supporting the strategy for environmental sustainability (Kadir et al. 2022).

This research elaborates on using the Paperbark trees (*M. leucadendron*) by the Marind Anim indigenous community in Merauke, South Papua. Understanding utilization by a traditional community informs the community efforts and helps them learn to extract resources from nature wisely (Kadir et al. 2020; Merritt et al. 2021). Traditional ecological knowledge systems are important not only to conserve nature but also to adapt to

climate change and the changes in socio-ecological systems (Makondo and Thomas 2018; Simbiak et al. 2019).

MATERIALS AND METHODS

Location and time

This research was conducted in Merauke District, South Papua Province, Indonesia (Figure 1). Data were collected between 2022 and 2023. The sample was taken from eight villages representing six districts, namely Wasur (Merauke District), Yanggandur, Rawa Biru, and Sota (Sota District), Muting (Muting District), Urumb (Semangga District), Koiburse (Malind District), and Bersehati (Tanah Miring District). Based on preliminary information, it was found that the site was a Paperbark forest and a source of wood products, so this location was chosen as the research site. In general, this study was conducted in the lowland area of Merauke Regency which is located at an altitude between 4-44 m asl., temperature 26-31.5°C (Kadir et al. 2022 with an average of 26.3°C, humidity 79-89%, rainfall 900-1600 mm per year (BPS 2023), and soil pH conditions 5.0-6.0, and suitable for agricultural land (Kadir et al. 2022).

The utilization of Paperbark trees by the Marind Anim people

Data were collected from observations and interviews with the indigenous people of the Marind Anim tribe in Merauke. The observations were carried out directly in the forest and the residents' houses in the villages. The observations were conducted to observe how the community uses the Paperbark trees to meet their needs.

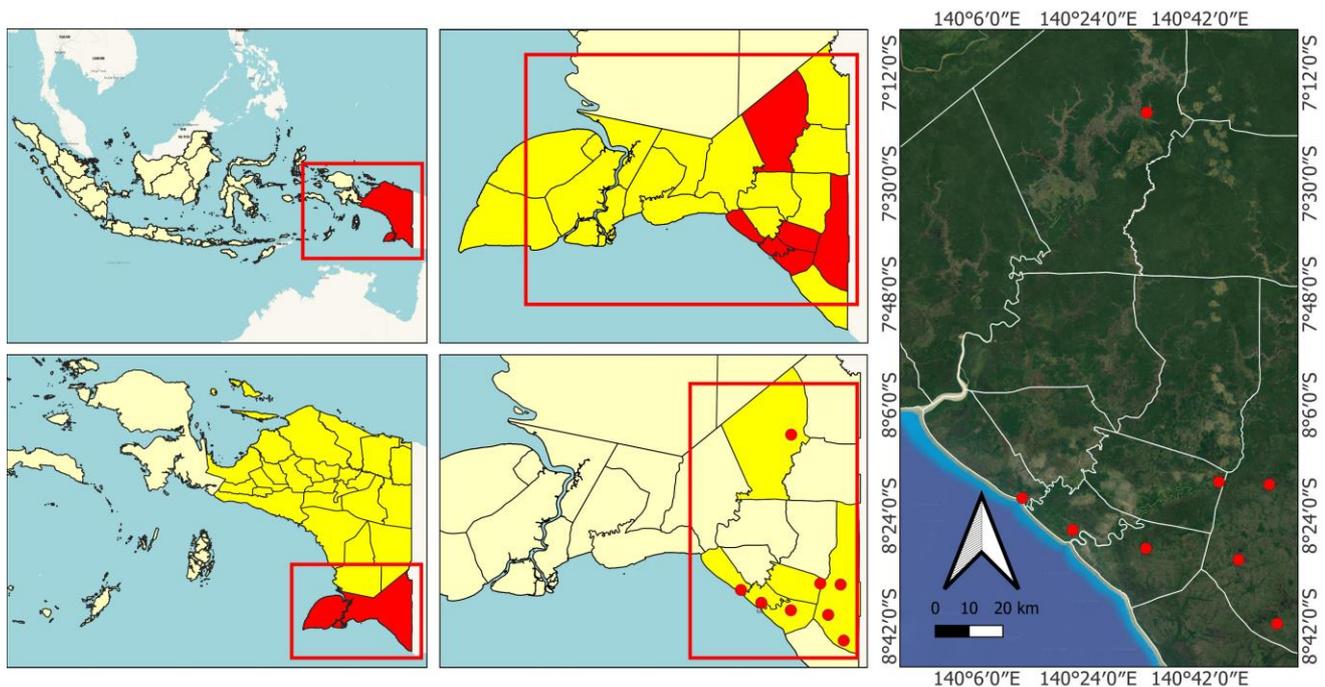


Figure 1. Sampling locations of Paperbark tree (*Melaleuca leucadendron*) in Merauke, South Papua, Indonesia

This research was conducted with interview techniques using a semi-structured questionnaire. The interviews were conducted with respondents from eight villages representing various Marind Anim indigenous community groups. Interviews were conducted openly with 75 respondents representing 8 villages, namely Wasur, Yanggandur, Rawa Biru, Sota, Muting, Urumb, Koiburse, and Bersehati. Respondents consisted of village heads/customary elders, communities and Paperbark wood users. In general, the variables measured in the interviews were community knowledge related to Paperbark trees, the utilization of plant parts, and for what needs the plant parts were used.

Data analysis

The observation data were analyzed descriptively and qualitatively, and the interview data were processed in Microsoft Excel to calculate the percentage of respondents. In addition, the observation results are displayed in tables and figures.

RESULTS AND DISCUSSION

The distribution of Paperbark trees (*M. leucadendron*)

The findings show that the Paperbark plant (*Melaleuca leucadendron*) is distributed in the lowland areas of southern Papua. It is endemic in Merauke, Boven Digoel, Mappi, and Asmat districts and grows in smaller quantities in the Mimika district. The land characteristic of this area is swampy, with standing water during the rainy season and a lower volume of groundwater during the dry season. According to Kadir et al. (2020) and Tanjung et al. (2020), the land in this area can be categorized as young peatland. The same *M. leucadendron* also grows in swamps and peatlands in South Sumatra, as recorded in a study by Helfiansah et al. (2013), indicating that the distribution of the species is broad across the country. Indeed, according to the GBIF Backbone Taxonomy data (2022), the distribution of *M. leucadendron* is broad across the world (Figure 2).

The utilization of Paperbark trees by the Marind Anim people

The Marind Anim people utilize Paperbark trees for various purposes (Figures 3 and 4). They depend on paperbark trees for livelihood, especially housing (Tables 1 and 2). For example, they use Paperbark trunks for house structures (unprocessed) and turn them into logs (5 x 5, 5 x 10, 10 x 10 cm) or boards (2 x 20 cm). In addition to housing material, they also utilize Paperbark trunks for firewood. Meanwhile, the bark can be used for house roofs, mats for crops, and firewood. Apart from *kayu bus* (*M. leucadendron*), the Marind Anim people are also familiar with another plant of the same group, *Eucalyptus* sp. The tribe calls it *kayu rahe*, whose leaves can be distilled for essential oil, i.e., Eucalyptus.

The interview also shows that the Marind Anim people can identify and show the location of *kayu bus* plants (*M. leucadendron*). They also know which parts to use for their needs, including the logs. Most of them (95%) have used the bark, and only the remaining 5% have never used it, most (65%) have experience utilizing the leaves, 17% were unsure, and 18% have never used them. No one knows what roots are used for, and some (22%) were doubtful if they have used the roots for traditional medicine. The roots are for traditional medicine (78%) from the interviews, as elder people have told them (Table 1).

Regarding construction material, the majority have used Paperbark timber for house construction (92.31%) and tree bark for roofing (88%) (Figures 5 and 6). A few (23%) use the bark for other purposes, such as mats to store agricultural produce. Based on interviews, the findings also show that some people distilled the leaves for their essential oil with assistance from the government and NGOs, especially in the Wasur National Park area. The percentage of the population with experience with the distillation of Paperbark leaves is high (54%) because the essential oil produced has a high economic value. According to Noumi et al. (2011), Patramurti et al. (2020), and Isah et al. (2023), the essential oil in *M. leucadendron* leaves is rich in medicinal compounds (Table 2).

Table 1. The local people's knowledge of the use of Paperbark trees (*Melaleuca leucadendron*) for daily needs

| Statement | Respondent (%) | | |
|--|----------------|----------|-------------|
| | Knowing | Doubtful | Not knowing |
| I know Paperbark trees (<i>M. leucadendron</i>) | 100 | 0 | 0 |
| I can show the location of Paperbark trees | 100 | 0 | 0 |
| I know the benefits of Paperbark trees | 100 | 0 | 0 |
| I know which tree parts to be used | 100 | 0 | 0 |
| I have used the wood | 100 | 0 | 0 |
| I have used the bark | 95 | 0 | 5 |
| I have used the leaves | 65 | 17 | 18 |
| I have used the roots | 0 | 22 | 78 |
| I have used and processed Paperbark wood for housing | 92 | 6 | 2 |
| I have used and processed the bark for roofing | 88 | 1 | 11 |
| I have distilled essential oils from the leaves | 54 | 21 | 25 |
| I have used the wood for firewood | 100 | 0 | 0 |
| I have used the wood other than for housing (e.g., using the bark for mats/containers of agricultural produce) | 23 | 16 | 61 |

Notes: n= 75 respondents

Table 2. The parts of the Paperbark tree (*Melaleuca leucadendron*) utilized by the traditional Marind Anim people in Merauke, South Papua, Indonesia

| The tree part (organ) | Utilization | Sources of information |
|-----------------------|---|--|
| Trunk | The timber is used as the main material for housing structure The bark is used for roofing and mats for agricultural produce The twigs are used for firewood. Building materials, bridge floors, processing of wood products, charcoal, firewood, etc. | The current research Purwanto (2015) |
| Root | Traditional medicine | The current research |
| Leaves | Used to make eucalyptus oil (essential oil) Essential oils are useful for herbal remedies, including antiseptics, antispasmodics, antineuralgics, and antirheumatics, as well as for material in cosmetics manufacturing. | The current research; Pujiarti et al. (2011) Pujiarti et al. (2011) Isah et al. (2023) Patramurti et al. (2020) |
| Flowers | Biological activity in antifilarial, antifungal, antibacterial Antioxidant and photoprotective activities in human keratinocytes | Isah et al. (2023) Silva et al. (2020) |
| Fruit | Biological activities, i.e., antifungal and antibacterial | Isah et al. (2023), Monzote et al. (2020) |



Figure 2. The distribution of Paperbark trees (*Melaleuca leucadendron*) in the world (GBIF Backbone Taxonomy 2022)

In random observations at several locations, measuring the diameter of the largest plants, show that the diameter of most trees in Merauke is <50 cm and the demand for Paperbark timber is high due to the prevalent use of the timber. This could be the reason why trees with a large diameter are rare. However, another significant use of Paperbark trees is not only the wood (Kadir et al. 2020) but also the leaves, namely for essential oil (Patramurti et al. 2022). In this case, Pasaribu et al. (2021) suggest that a sound management system for Non-Timber Forest Products (NTFPs) will help optimize the benefits for the community's welfare and forest sustainability.

The Marind Anim indigenous community in Merauke utilizes Paperbark trees in the most optimum possible methods. This makes sense because the plant is endemic and readily available in the surrounding environment. Besides, the other plant species diversity that the community can utilize is limited in this area. Other areas in Papua and Indonesia have more diverse species, meaning there are other trees for housing structures. According to Yarman and Damayanti (2012), there are 10 forest classes in Merauke, especially in the Wasur National Park (WNP) area: (i) the pre-dominantly *Melaleuca* sp. forest, (ii) the co-dominant *Melaleuca* sp and *Eucalyptus* sp forest, (iii)

the sparse forest, (iv) the coastal forest, (v) the seasonal forest, (vi) the riverside forest, (vii) the mangrove forests, (viii) the savanna, (ix) the grasslands, and (x) the swamp grasslands. The types of plants that dominate the WNP area are *Melaleuca* sp., *Asteromyrtus symphiocarpa*, *Eucalyptus* sp., *Acacia* sp., *Alstonia actinophylla*, *Dilenia alata*, *Banksia dentata*, *Pandanus* sp., *Cycas* sp., *Amorphophallus* sp., orchids, and others.

According to Febryano et al. (2021), local communities often utilize tree species for their housing needs that are available in their environment. For example, in Dempo Tengah District, Pagaralam City, South Sumatra Province, people use *mersawa* (*Anisoptera* sp.), *surian* (*Toona sureni* Merr.), and *rasamala* (*Altingia excelsa* Noronha) wood to make traditional house called *Besemah* (*ghumah baghi*) houses. Furthermore, a traditional house can reflect a particular tribe's identity, so their characteristics are often distinctive and unique. Other regions in Indonesia also have unique housing construction characteristics, which can be attributed to using local materials. According to Suharno et al. (2023), in Papua, house construction is mainly made from ironwood (*Intsia bijuga*). However, this wood is mostly available in the northern Papua region.

In some villages in Merauke, cutting down paperbark trees requires permission from the elders (tribal heads) and coordination with the village head. In WNP areas, after obtaining permission from the village head or tribal elders, the licensing process starts by requesting approval from the WNP Hall management and a permit for logging in the National Park area. This proves the community has rules for managing forests based on local wisdom, supported by stakeholder regulations, namely the WNP area managers.

Limited building materials in Merauke significantly affect the development of housing facilities. Most materials, including stones and sand, are obtained from other regions, such as Sulawesi and Java. In this condition, housing made of brick walls is limited due to the high costs of these conventional materials. Therefore, using existing, local, natural resources for housing construction is preferable in Merauke. Paperbark trees are the first choice because they are more readily available than other woods and housing materials.

Based on the interview results, people consider the durability of Paperbark wood for house construction to be satisfactory; the primary use is on frames and structures. Good quality wood can last up to five years on average; if protected (not exposed to water), it can last up to 12 years. The Marind Anim indigenous people also use the bark for roofing; they prefer this material to others because its durability is up to 12 years. Additionally, the use of bark as roofing creates a more comfortable atmosphere. It makes the room temperature warmer when it rains and cooler under the sun's heat. In addition, Fujii et al. (2018) revealed houses with "hiwada" roofs in Japan. *Hiwada* is a harvestable bark material from the outer bark of large-diameter hinoki (*Chamaecyparis obtusa*) trees that are more than 70 years old and roughly 10-year intervals. Japan has about 700 *hiwada* roofed wooden buildings designated National Treasures and Important Cultural Properties. The use of *hiwada* is quite high quality for roofing, as evidenced by these roofs being replaced every 30 to 40 years.



Figure 3. One of the *bifak* (rest houses) in Yanggandur Village, Merauke, South Papua, Indonesia was constructed using natural material



Figure 4. Paperbark trees (*Melaleuca leucadendron*) are processed into various materials. A. Wooden plank blocks 5 x 10 cm, B. Wooden board measuring 2 x 20 cm, C. Wood logs with a small diameter for roof frames, D. Bark for roofing



Figure 5. Morphology of a Paperbark trunk (*Melaleuca leucadendron*). A. Plant stems, B. Stems with bark that peels easily, C. A barked stem, and D. The stem has grown back its bark



Figure 6. The tree bark of *Melaleuca leucadendron* is used for various needs. A. The bark, B. The bark ready to be used for various needs, C. The bark used as substitute mats to store agricultural harvests, D. The bark for roofing

The Marind Anim people bark at the trees by selecting the good trunks—the straight ones with a large diameter. As such a trunk diameter, the bark will be long and wide. The diameter of the trunk suitable for barking is above 15 cm. The bark is taken by peeling it vertically using a machete. The outer thin layer of the stem is usually cleaned first. The bark's depth is up to the middle part of the trunk. The bark used for roofing is usually between 80 and 120 cm long and between 60 and 80 cm wide (Figure 6). The roof made from the bark usually consists of two layers; this ensures the roof remains durable and does not leak due to rainwater. The skin is usually arranged from the bottom

corner to the top of the roof, like building a metal (zinc) roof. Meanwhile, their wood can be used for various purposes. The bark parts (*bus paal*) are also one of the ingredients used to make sago. According to Kadir et al. (2022), sago is one of the main local food sources for Merauke's Marind Anim indigenous community.

Forest and Paperbark tree conservation in Merauke

Paperbark forests are a habitat for various types of animals such as weaver ants (*Oecophylla* sp. among others), various types of birds (including white parrots, *Cacatua*

sp.), termites (*Macrotermes* sp.) that produce nests called *Musamus*, kangaroos (*Macropus*), wild boars (*Sus* sp.), deer (*Cervus* sp.), cassowaries (*Casuarius* sp.), and various other animals. According to Yarman and Damayanti (2012), various types of mammals are found in WNP, including kangaroos (*Macropus agilis*, *Dorcopsis veterum*, *Thylogale brunii*), forest civets (*Dasyurus spartacus*) and spotted cuscus (*Spilocuscus petaurus breviceps*) which are known locally as squirrels.

Furthermore, Yarman and Damayanti (2012) also revealed that there are around 403 bird species, 74 of which are endemic to Papua. It is also estimated that 114 species are protected, including the Papuan garuda (*Aquila gurneyi*), paradise bird (*Paradisaea apoda*), cassowary (*Cassowary*), eagle (*Circus* sp.), and kestrel (*Accipiter* sp.). The Paperbark-dominated wetlands in WNP are also important habitats for migratory birds from Australia and New Zealand, such as Scolopacidae, Haematopodidae, Pelecanidae, Phalaropodidae, Recurvirostridae, Laridae, Anatidae, Charadriidae, and Thresciornithidae.

In this swampy lowland area, sago plants also grow, becoming a food source for the community. The community also revealed that many Paperbark forests are hunting areas in various interviews. This preserved nature allows the people to maintain a hunting and gathering culture (sago palming). Therefore, traditional people understand that forests are important habitats for various creatures, which are invaluable to their livelihood needs. Therefore, forests are a community food source (Ickowitz et al. 2016) and can be developed as recreational areas (Kaeslin and Williamson 2010; Karjalainen et al. 2010). Therefore, traditional communities understand that forests are important habitats for a variety of creatures, which are invaluable to their livelihood needs.

The Paperbark plant (*M. leucadendron*) is also associated with orchids (Orchidaceae) and ant nest plants (*Myrmecodia*), which grow and develop well on tree trunks, branches, and twigs. According to Dirgantara et al. (2015), ant nest plants originating from Merauke have excellent quality as traditional medicine. The *kayu bus* or Paperbark Forest area is also associated with *kayu rahe* (*Eucalyptus* sp.), which produces essential oil and is often enjoyed by the locals.

People who live around forests should be able to manage forests in their neighborhoods wisely. In the WNP area, dominated by Paperbark plants, indigenous people have lived for a long time. According to Yarman and Damayanti (2012), the WNP area is around 413,810 hectares and is inhabited by four indigenous ethnic groups, namely the Malind Imbuti, Kanume, Marori Men Gey, and Yeinan tribes. They have lived for generations and have customary rights to all land in the area; the relationship between local communities and the forest environment determines its future. According to Patramurti et al. (2020) and Silva et al. (2020), forests and *Melaleuca* plants, essential for people's livelihood, need conservation efforts. The utilization and availability of the plants in nature must be managed well to keep them sustainable because they are harvested for wood and non-timber forest products, which may be better with the same comparison. Pandey et al. (2016) revealed that forest biomass contains about 40%

carbon by weight, along with hydrogen (6.7%) and oxygen (53.3%), making it a great source of carbon reserves. Bolton and Greenway (1997) showed that *Melaleuca* plants were used to reconstruct artificial wetlands in Australia. In addition, Puvača et al. (2020) revealed something that may not be familiar: Essential oils can be used to improve the quality of promising chicken egg quality. The right strategy to maintain the interests of natural preservation and human needs for bus wood is to educate the community by carrying out selective logging on trees that are suitable for use. Meanwhile, timber utilization regulations must be made in collaboration between the local government, WNP area managers, and indigenous communities.

According to Kosmaryandi (2012), the national park areas are the territory of indigenous peoples but have never been managed with the consideration of indigenous peoples. On the contrary, the PP 68 letter e criteria explicitly state that no residents should be in the national park area. That means the national park's management only considers the population's dependence on the area. The criteria in PP. 68 do not consider the socio-cultural aspects of indigenous communities. This has resulted in a lack of harmony in the national park's management. The regulation may also raise a tenure conflict caused by the closed access for indigenous communities to the natural resources that become their source of livelihood.

During the dry season, forest fires often occur because the bark is thick; the fires will last long and be difficult to extinguish. Fortunately, after the fire, the Paperbark plant will not die; over time, it will grow new skin and return to its previous state. According to Chungu et al. (2020), forest fires can alter soil nutrient availability and accelerate *Eucalyptus* growth. However, according to Barreiro and Díaz-Raviña (2021) and Sharma and Thapa (2021), fires can create imbalances in the overall ecology and cause damage to flora and fauna, as well as microorganisms. Thus, following El Hajal and Bechara (2019) and Feng (2021), fire prevention efforts must be made to prevent forest destruction.

The Paperbark wood in wooden blocks shape has a high-value market in Merauke, reaching 2.5 million rupiahs (166 USD) per cubic meter. Other types of wood trunks (such as *kayu rahe* or *Eucalyptus* sp.) are non-straight, so their use is limited, even though they may have better quality. In this case, most people prefer Paperbark wood for building houses, and *Kayu rahe* wood is usually preferred for making frames, windows, shelves, cupboards, etc. Paperbark wood materials sources in Merauke City mostly come from the Wasur, Muting, Jagebob, Kurik, and Sota.

All in all, it can be concluded that the Marind Anim indigenous people depend on their environment to fulfill their daily needs. Paperbark wood is a source of house construction materials and other necessities of life. There needs to be an agreement through indigenous community regulations in accordance with local wisdom supported by the regional regulatory system and the WNP Area manager so that the Paperbark management system can be carried out wisely. With the versatile use of Paperbark wood by the community in the lowland areas of Merauke, it is necessary

to implement a sound forest management system to maintain its sustainability.

ACKNOWLEDGMENTS

We thank Gito, Agustinus Mahuze, and Yohana Reawaruw for assisting in the Merauke, South Papua, Indonesia sample collection. We also thank the Head of Research and Community Service (LPPM) Universitas Cenderawasih, Jayapura, Indonesia for the support.

REFERENCES

- Allan JI, Auld G, Cadman T, Stevenson H. 2022. Comparative fortunes of ecosystem services as an international governance concept. *Glob Policy* 13 (1): 62-75. DOI: 10.1111/1758-5899.13036.
- Barreiro A, Díaz-Raviña M. 2021. Fire impacts on soil microorganisms: Mass, activity, and diversity. *Curr Opin Environ Sci Health* 22: 100264. DOI: 10.1016/j.coesh.2021.100264.
- Bennett EM, Cramer W, Begossi A et al. 2015. Linking biodiversity, ecosystem services, and human well-being: Three challenges for designing research for sustainability. *Curr Opin Environ Sustain* 14: 76-85. DOI: 10.1016/j.cosust.2015.03.007.
- Bolton KGE, Greenway M. 1997. A feasibility study of *Melaleuca* trees for use in constructed wetlands in subtropical Australia. *Water Sci Technol* 35 (5): 247-254. DOI: 10.2166/wst.1997.0209.
- BPS [Badan Pusat Statistik]. 2023. Kabupaten Merauke dalam angka 2023. BPS Kabupaten Merauke. [Indonesian]
- Bonnedahl KJ, Heikkurinen P, Paavola J. 2022. Strongly sustainable development goals: Overcoming distances constraining responsible action. *Environ Sci Pol* 129: 150-158. DOI: 10.1016/j.envsci.2022.01.004.
- Børresen ST, Ulimboka R, Nyahongo J, Ranke PS, Skjaervø GR, Røskoft E. 2023. The role of education in biodiversity conservation: Can knowledge and understanding alter locals' views and attitudes towards ecosystem services?. *Environ Educ Res* 29 (1): 148-163. DOI: 10.1080/13504622.2022.2117796.
- Ceballos G, Ehrlich PR, Barnosky AD, García A, Pringle RM, Palmer TM. 2015. Accelerated modern human-induced species losses: Entering the sixth mass extinction. *Sci Adv* 1 (5): e1400253. DOI: 10.1126/sciadv.1400253.
- Chungu D, Ng'andwe P, Mubanga H, Chileshe F. 2020. Fire alters the availability of soil nutrients and accelerates growth of *Eucalyptus grandis* in Zambia. *J For Res* 31 (5): 1637-1645. DOI: 10.1007/s11676-019-00977-y.
- Deutsch N. 2014. Human dependency on nature framework: Qualitative approaches background study. People in Nature Working Paper No. 1. IUCN and CEESP, Gland, Switzerland.
- Dirgantara S, Dewi K, Raya JN, Simanjuntak TL. 2015. Botanical and phytochemical studies of three species of ant nest plants from Merauke Regency, Papua Province. *Jurnal Farmasi Sains dan Terapan* 2 (2): 20-22. DOI: 10.33508/jfst.v2i2.718. [Indonesian]
- El Hajal A, Bechara J. 2019. Calculating the social return on investment of 'firewise' in Lebanon. Study developed under the USAID-funded Livelihoods in Forestry Project.
- Feng H. 2021. Exploration and thinking on related mechanisms of forest fire prevention. In: Strielkowski W, Black JM, Butterfield SA, Chang C-C, Cheng J, Dumanig FP, Al-Mabuk R, Urban M, Webb S. *Advances in Social Science, Education and Humanities Research; Proceedings of the 2021 International Conference on Social Science: Public Administration, Law and International Relations (SSPALIR 2021)*. Moscow, 16-17 June 2021. DOI: 10.2991/assehr.k.210916.003.
- Febryano IG, Harum OMA, Wulandari C, Hidayat W, Banuwa IS, Prasetya H, Iswandaru D, Novriyanti N, Duadji N, News T, Zulfiani D, Ichsan AC, Salampessy ML. 2021. Raw material of Besemah traditional house construction in Indonesia. *Folia For Pol A - Forestry* 63 (1): 74-80. DOI: 10.2478/ffp-2021-0008.
- Fedele G, Donatti CI, Bornacelly I, Hole DG. 2021. Nature-dependent people: Mapping human direct use of nature for basic needs across the tropics. *Glob Environ Change* 71: 102368. DOI: 10.1016/j.gloenvcha.2021.102368.
- Fujii T, Osumi K, Kubono T. 2018. Resin canals in "hiwada", bark of hinoki (*Chamaecyparis obtusa*) as roofing material. *Bull FFPRI* 17 (4): 305-316. DOI: 10.20756/ffpri.17.4_305.
- Gatenby S, Townley P. 2014. Preliminary research into the use of the essential oil of *Melaleuca alternifolia* (tea tree oil) in museum conservation. *AICCM Bull* 28: 67-70. DOI: 10.1179/bac.2003.28.1.014.
- GBIF Backbone Taxonomy. 2022. *Melaleuca leucadendra* (L.) L. in GBIF Secretariat. DOI: 10.15468/39omei.
- Helfiansah R, Sastrohamidjojo H, Riyanto. 2013. Isolation, identification and purification of 1,8 cineol compounds in eucalyptus oil (*Malaleuca leucadendron*). *Asian J Syst Eng* 1 (1): 19-24. DOI: 10.22146/ajse.v1i1.2350. [Indonesian]
- Ickowitz A, Rowland D, Powell B, Salim MA, Sunderland T. 2016. Forests, trees, and micronutrient-rich food consumption in Indonesia. *PLoS One* 11 (5): e0154139. DOI: 10.1371/journal.pone.0154139.
- Isah M, Rosdi RA, Wahab W-N-AWA, Abdullah H, Sul'ain MD, Ishak WRW. 2023. Phytoconstituents and biological activities of *Melaleuca cajuputi* Powell: A scoping review. *J Appl Pharm Sci* 13 (1): 10-23. DOI: 10.7324/JAPS.2023.130102.
- Kadir A, Suharno, Reawaruw Y, Komari, Mahuze A. 2022. Ethnobotanical knowledge of Marind-Anim Tribe in utilizing sago (*Metroxylon sagu*) in Merauke, Papua, Indonesia. *Biodiversitas* 23 (1): 264-272. DOI: 10.13057/biodiv/d230132.
- Kadir A, Tanjung RHR, Suharno, Rumahorbo BT, Reza MA. 2020. Soil physicochemical and ethnobiological studies on the peat swamp forests of Southern Papua, Indonesia. *Biodiversitas* 21 (4): 1714-1722. DOI: 10.13057/biodiv/d210454.
- Kaeslin E, Williamson. 2010. Forests, people and wildlife: Challenges for a common future. *Unasylva* 61 (236): 4-10.
- Karjalainen E, Sarjala T, Raitio H. 2010. Promoting human health through forests: overview and major challenges. *Environ Health Prev Med* 15 (1): 1-8. DOI: 10.1007/s12199-008-0069-2.
- Kosmaryandi N. 2012. Wasur National Park, management of conservation area in indigenous community land. *Media Konservasi* 17 (1): 6-15. [Indonesian]
- Makhubele L, Chirwa PW, Sheppard JP, Tshidzumba RP, Araia MG, Kahle H-P. 2022. Conservation of tree species richness in a traditional agroforestry landscape in the Vhembe Biosphere Reserve, South Africa. *Forests* 13 (11): 1766. DOI: 10.3390/f13111766.
- Makondo CC, Thomas DSG. 2018. Climate change adaptation: Linking indigenous knowledge with western science for effective adaptation. *Environ Sci Policy* 88: 83-91. DOI: 10.1016/j.envsci.2018.06.014.
- Merritt E, Peterson A, Evans S, Marston SA, Zuiker S. 2021. Learning about culture and sustainable harvesting of native plants garden-based teaching can foster appreciation of indigenous knowledge. *Teach Teach* 58 (4): 69-73.
- Mekonen S. 2020. Coexistence between human and wildlife: The nature, causes and mitigations of human wildlife conflict around Bale Mountains National Park, Southeast Ethiopia. *BMC Ecol* 20: 51. DOI: 10.1186/s12898-020-00319-1.
- Monzote L, Scherbakov AM, Scull R, Satyal P, Cos P, Shchekotikhin AE, Gille L, Setzer WN. 2020. Essential oil from *Melaleuca leucadendra*: Antimicrobial, antikinoplastid, antiproliferative and cytotoxic assessment. *Molecules* 25: 5514. DOI: 10.3390/molecules25235514.
- Noumi E, Snoussi M, Hajlaoui H, Trabelsi N, Ksouri R, Valentin E, Bakhrouf A. 2011. Chemical composition, antioxidant and antifungal potential of *Melaleuca alternifolia* (tea tree) and *Eucalyptus globulus* essential oils against oral *Candida* species. *J Med Plant Res* 5 (17): 4147-4156.
- Pandey R, Hom SK, Harrison S, Yadav VK. 2016. Mitigation potential of important farm and forest trees: A potentiality for clean development mechanism afforestation reforestation (CDM A R) project and reducing emissions from deforestation and degradation, along with conservation and enhancement of carbon stocks (REDD+). *Mitig Adapt Strateg Glob Chang* 21: 225-232. DOI: 10.1007/s11027-014-9591-2.
- Pasaribu G, Winarni I, Gusti REP, Maharani R, Fernandes A, Harianja AH, Saragih GS, Turjaman M, Tampubolon AP, Kuspradini H, Lukmandaru G, Njurumana GN, Sukito A, Aswandi A, Kholibrina CR. 2021. Current challenges and prospects of Indonesian Non-Timber Forest Products (NTFPs): A review. *Forests* 12 (12): 1743. DOI: 10.3390/f12121743.
- Patramurti C, Amin R, Nastiti CMRR, Hariono M. 2020. A review on the potency of *Melaleuca leucadendron* leaves solid waste in wood

- preservation and its in silico prediction upon biological activities. *Intl J For Res* 2020: 8885259. DOI: 10.1155/2020/8885259.
- Pujiarti R, Ohtani Y, Ichiura H. 2011. Physicochemical properties and chemical compositions of *Melaleuca leucadendron* leaf oils taken from the plantations in Java, Indonesia. *J Wood Sci* 57: 446-451. DOI: 10.1007/s10086-011-1183-0.
- Purwanto D. 2015. The properties of particleboard made of galam (*Melaleuca leucadendra* L.) tree bark bonded with urea formaldehyde. *Jurnal Penelitian Hasil Hutan* 33 (2): 135-144. [Indonesian]
- Puvača N, Lika E, Cocoli S, Kika TS, Bursič V, Vuković G, Simin MT, Petrovič A, Cara M. 2020. Use of tea tree essential oil (*Melaleuca alternifolia*) in laying hen's nutrition on performance and egg fatty acid profile as a promising sustainable organic agricultural tool. *Sustainability* 12 (8): 3420. DOI:10.3390/su12083420.
- Roe D, Booker F. 2019. Engaging local communities in tackling illegal wildlife trade: A synthesis of approaches and lessons for best practice. *Conserv Sci Pract* 1 (5): e26. DOI: 10.1111/csp2.26.
- Sangha KK, Brocque AL, Costanza R, Cadet-James Y. 2015. Ecosystems and indigenous well-being: An integrated framework. *Glob Ecol Conserv* 4: 197-206. DOI: 10.1016/j.gecco.2015.06.008.
- Sharma K, Thapa G. 2021. Analysis and interpretation of forest fire data of Sikkim. *For Soc* 5 (2): 261-276. DOI: 10.24259/fs.v5i2.10931.
- Silva LSB, Perasoli FB, Carvalho KV, Vieira KM, Lopes MFP, de Souza GHB, dos Santos ODH, Freitas KM. 2020. *Melaleuca leucadendron* (L.) L. flower extract exhibits antioxidant and photoprotective activities in human keratinocytes exposed to ultraviolet B radiation. *Free Radic Biol Med* 159: 54-65. DOI: 10.1016/j.freeradbiomed.2020.07.022.
- Simbiak M, Supriatna J, Nisyawati, Walujo EB. 2019. Current status of ethnobiological studies in Merauke, Papua, Indonesia: A perspective of biological-cultural diversity conservation. *Biodiversitas* 20 (12): 3455-3466. DOI: 10.13057/biodiv/d201201.
- Suharno, Tanjung RHR, Sufaati S, Agustini V. 2016. Wati (*Piper methysticum* L.) medicinal plant: The ethnobiological and ethnomedicinal values of the Marind tribe in Merauke, Papua, Indonesia. *Biodiversitas* 17 (2): 814-822. DOI: 10.13057/biodiv/d170259.
- Suharno, Zebua LI, Keiluhu HJ. 2023. Usaha Konservasi Merbau (*Intsia* spp.), Tanaman Khas Indonesia. IPB Press, Bogor. [Indonesian]
- Tanjung RHR, Suharno, Rumahorbo BT, Reza MA, Akhmad. 2020. Characteristics of peatland chemicals and their association with the diversity of dominant plants in Papua. *IOP Conf Ser Earth Environ Sci* 575: 012082. DOI: 10.1088/1755-1315/575/1/012082.
- Viscogliosi C, Asselin H, Basile S, Borwick K, Couturier Y, Drolet M-J, Gagnon D, Obradovic N, Torrie J, Zhou D, Levasseur M. 2020. Importance of Indigenous elders' contributions to individual and community wellness: Results from a scoping review on social participation and intergenerational solidarity. *Can J Public Health* 111 (5): 667-681. DOI: 10.17269/s41997-019-00292-3.
- WWF [World Wildlife Fund]. 2022. Living Planet Report 2022-Building a naturepositive society. Almond REA, Grooten M, Bignoli JD, Petersen T (eds). WWF, Gland, Switzerland.
- Yarman Y, Damayanti EK. 2012. Utilization and conservation action of *Asteromyrtus symphyocarpa* in Wasur National Park. *Med Konserv* 17 (2): 85-93. [Indonesian]