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Research Article
Ecological and Ethnobotanical Facet of 'Kelapa Hutan' (*Pandanus* Spp.) and Perspectives Towards its Existence and Benefit

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Abstract

Background and Objective: *Pandanus* species are spread across the tropical New Guinea Forest and have long been extracted for food. In this study, the ecological and ethnobotanical aspects of *Pandanus* spp. were investigated. The objectives of the study were to highlight types of edible *Pandanus* spp. through their taxonomical characteristics, ecological distribution and fruit properties and to describe how traditional communities manage their existence and traditional values by way of ethnobotany and conservation. **Methodology:** To identify the potency and distribution of the edible Pandanus, continuous strip-sampling was applied to the sampling plots with an intensity of 5%. Temperature and humidity were measured directly under trees. The edible *Pandanus* specimens were identified by key experts and identification books. The thermogravimetric and Kjeldahl methods were implemented to identify nutrient contents. A semi-structural interview was implemented, which included questions on the management of Pandanus fruit and its social status among communities. Pearson's correlation analysis was implemented to identify any relationship between temperature, humidity and fruit productivity. This analysis was performed using R statistical program. **Results:** Two edible *Pandanus* species were identified based on each characteristic: *Pandanus brosimos* Merr. and Perry dan *Pandanus julianettii* Mart. both exhibited similarities, despite variations in the taste and color of the fruit and the hardness of the rind. Ecological conditions were favorable for both type of edible Pandanus. The soil had a maximum solum layer up to 30 cm depth, with an ideal mean temperature of 21.95°C and average of humidity of 85%. However, Pearson's correlation between temperature and fruit productivity as well as humidity and fruit productivity were negative with p-values of 0.159 and 0.225, respectively. The fruit was high in nutrients especially fat and vitamin C. Due to their significance and contribution, both types of edible Pandanus have been developed in private gardens in local communities. The fruit has been used in cultural and ceremonial events among the communities in the high-land of Papua, Indonesia. **Conclusion:** This study revealed that edible Pandanus species contribute significantly towards local communities in the high-land of Indonesian New Guinea.

Key words: Edible *Pandanus* spp., Kelapa hutan, high-land community, *Pandanus brosimos*, *Pandanus julianettii*

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Papua is a unique region of land cover, with the high abundance of natural characteristics and range of various biogeographical features. Historical information on the Indonesian island of New Guinea associated with its geological formation and the influence of physiological traits are difficult to interpret[1-3]. Various habitats and ecosystems almost cover complete vegetation zones in the Asia-Pacific region, ranging from coastal regions to the high-lands and Alpine forests[4-7]. A long process of adaptation has led to the unique characteristics of Papuan flora, creating highly abundant flora in the island of Indonesian New Guinea[8].

The number of floristic species in Papua is predicted to be 20,000-25,000[4], with a 50-90% rate of endemism out of the 202 endemic genera spread across the Indonesian archipelago. Papua is considered to have the highest number of endemic in the region, with 124 and is also home to 54% of Indonesia's biodiversity[9-11]. Hyndman[12] reported that more than 66 genera of Pandanus occur along the New Guinea archipelago, of which seven bear edible fruits. However, such floristic species are unknown and biological and botanical information on these species as well as their range of distribution across the island have not been described. In addition, theie small-scale extraction and utilization for daily consumption using traditional method is not fully understood. Compared to other tropical regions in the world, 246 families of florisrtic plants from 1,500 genera are found in Papua. Atleast 124 genera of flowering plants in Papua are classified as endemic (compared with 59 endemic genera in Borneo Island, 17 genera in Sumatera Island and 10 genera in Java Island)[9].

The Forest People Programme[13] revealed that more than 250 tribes of indigenous people are spread from the coastal region to the high-mountain region of the Indonesian Province of Papua and West Papua. These indigenous communities have been extracting a wide range of forest resources, either flora or fauna, for subsistence in their daily life[14,15]. Interdependency towards the surrounding forests, however shows the huge variety in each community coupled with the distribution of tribes and customs. This pattern is a common scheme of adaptation to the environment and has been passed down over generations[16]. For example, people who live in coastal areas will adapt their lifestyle to this area and catch fish, whereas, middle land and high-land communities will extract forest resources to fulfill their basic needs, such as timber for housing and edible plants for nutrients and vitamins.

The shifting paradigm of forest management has changed the motivation of people in theie use of forest resources, from basic utilization to more commercial benefits[17,18]. With the high promise of benefits, some forest lands have transformed gradually into other commercial uses. Forest extractions in Papua have been managed in various ways, especially small-scale nontimber extractions. Traditional communities across the region are more customized in how they manage the lands and generate a co-benefit from the forests[19,20]. Applicable agroforestry models are developed to support the basic necessities of communities without causing any significant damage towards the forest and natural ecosystem.

"Kelapa hutan" is a common term used to describe an edible Pandanus plant species in Papua, which confers a wide range of benefits. Despite these benefits, a basic understanding of its scientific name and its description is often lacking. In this study, the basic taxonomy of the edible Pandanus and its general attributes are reaffirmed. The objective of this study was to improve understanding of the taxonomy of edible Pandanus through scientific descriptions and identifications based on the characteristics of the plant components. Furthermore, its socio-cultural values were determined and the ecological conditions required for the plant to grow in the high land region of the Indonesian New Guinea forest ecosystem were elucidated.

MATERIALS AND METHODS

Study area: This study was conducted in Tolikara regency, situated in the center of the Papuan island, Indonesia, during the summer season (June-September) of 2011. Even though this study was performed 6 years ago, the detailed information presented about Kelapa hutan is fully representative of the current status of the ecological and ethnobotanical features of edible Pandanus in Indonesia New Guinea. The district lies in high-lands with a total area of 14,564 km^{-2} [21]. The altitudinal of the area ranges from 1,400-3,300 m above sea level (Fig. 1). The area is surrounded by mountains with several small rivers flowing through it. Most the area is dominated by the slope (> 40%), especially in the center to the North. The climate is relatively wet with high precipitation throughout the year.

Data measurement

Plot design: A transect was set up purposively to determine the distribution of edible Pandanus species. This meant that the population and distribution of the edible Pandanus was considered prior to designing the transect. The continuous

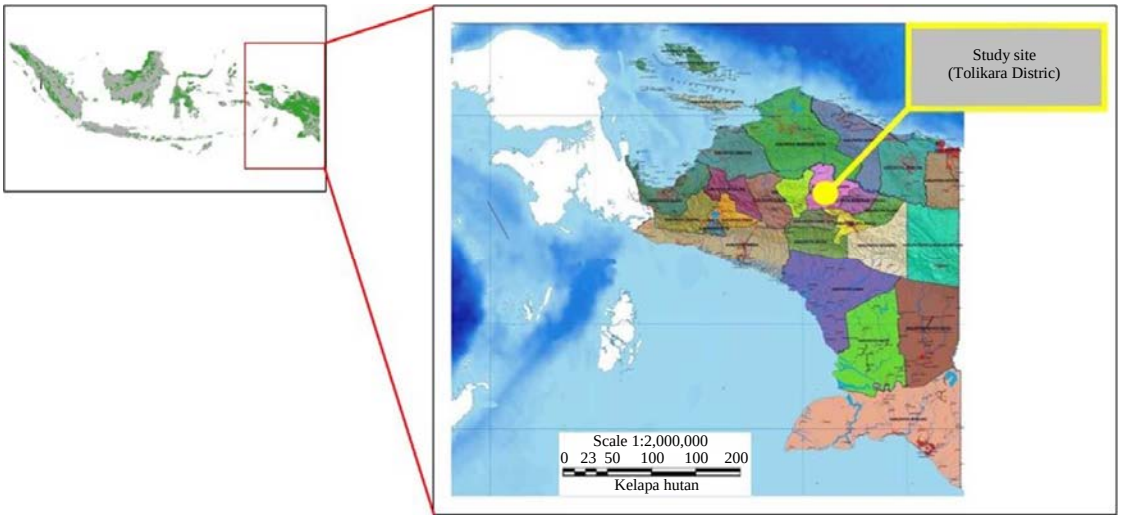

Fig. 1: Map showing the distribution of *Pandanus brosimos* and *Pandanus julianettii* in West Papua, Indonesia. The yellow dot in the center of the island highlights the study site (Tolikara District)

strip-sampling method was used to identify the potency and distribution. Sampling intensity was 5% with a 200 m long observation line and 100 m spacing between lines.

Data collection: Several ecological parameters such as temperature, humidity, soil nutrient, light intensity and association with surrounding vegetation were recorded. Temperature and humidity were measured directly under the tree using a hanging bimetallic thermohydrometer. Measurements were made each day at 12 pm to record data over 90 days. Soil samples were obtained using a hand-held soil corer under the study tree to analyze the nutrient components. Samples were placed in plastic to retain its condition and limit any disturbances. To determine the diameter of trees, diameter tape was applied at breast height (1.30 m). Additional observations considered the leaf, fruit, flower, bark and root. Association of species that grow surround edible Pandanus was identified within a radius of 10 m from the measured tree. Phenological observations were made to determine flowering and fruiting times and their frequency over a year. Fruits from 5-10 trees within the observation line were measured to determine the potential interval of fruiting trees as well as the fruiting potency of each tree. Fruiting potential was measured through interval assumptions, prior to that, early measurements were made using a 5 kg plastic bucket. Light intensity was estimated manually by standing under each study tree and gauging the percentage canopy cover.

Taxonomical identification: To reaffirm the taxonomical status, specimens were removed from a living tree. Atleast 5 replicates of each specimen were obtained. Leaves, fruits, flowers and other plant parts were carefully measured during the observation. Tools, such as a metal handle tree-cutting tool, a hand-pruning saw, plastic, alcohol, newspaper and duct tape were used to remove and maintain the specimen in a good condition for further analyses in the laboratory. Specimens were then taken to the Manokwariense Herbarium located in Manokwari, West Papua for analysis and identification. The identification was based on the advice of a taxonomy expert and a book containing additional guidance. In addition, the final specimen was distributed to the Bogoriense Herbarium in Bogor, West Java, Indonesia, Kew Garden Herbarium in the United Kingdom and PNG and Rijks Herbarium in the Netherland as part of collaborative research. The major aim of this study was to ascertain the taxonomical status of this species.

Ethnobotany: Socio-ethnobotanical data were collected through a direct semi-structured interview. People representing various communal statuses and strata were selected from around the study location. Interviewees included: Tribe leaders (two people) key informants (Five people) and tribe communities (about 20 % of the total people in the community), who had been extracting the edible Pandanus for generations. Questions were asked regarding the ecology, economy and culture of Kelapa hutan and its benefits for people and their environments.

Nutrient analysis: The nutritional contents of the edible Pandanus fruit were analyzed in the Food and Nutrient Laboratory, the University of Gadjah Mada, Yogyakarta. The

thermogravimetric method was used to analyze the water content and ash (Eq. 1 and 2). Fibers were analyzed by OACD official method that incorporated into the group of enzymatic gravimetric fiber analysis[22]. The Kjeldahl method[23] was implemented to assess the amount of protein. Total organic nitrogen was converted into ammonium sulfate. This was then neutralized with alkali and distillate into boric acid. The boric anion was then titrated to nitrogen. Fat was analyzed using the Goldfish method by calculating the loss of fat from the sample weight or disappeared fat weight[24]. The vitamin C concentration was determined via the redox titration method using iodine. When iodine was added during the titration, vitamin C was oxidized to dehydroascorbic acid, while the iodine was reduced to iodide ions[22].

$$\text{Water}(\%)(\text{wb}) = \frac{\text{Early weight} - \text{Constant weight}}{\text{Constant weight}} \times 100 \quad (1)$$

$$\text{Ash content}(\text{wb}) = \frac{\text{Ash weight}}{\text{Free sample of water weight}} \times 100\ (\%) \quad (2)$$

Statistical data analysis: The edible *Pandanus* spp. found in this study were subjected to detailed botanical description and identification. Plant parts were examined manually to determine the exact measurements. Pearson's correlation analysis was implemented to identify any relationship between temperature, humidity and fruit productivity. This analysis was performed using R statistical program 3.4.1 (R Development Core Team, 2017).

RESULTS

Kelapa hutan in Papua: The term used to describe kelapa hutan in Papua is intended for an edible Pandanus species. Based on the finding of this study, two species of edible Pandanus are found in Tolikara District of Papua, *Pandanus brosimos* Merr. and Perry dan *Pandanus julianettii* Mart. However, more variants of the edible Pandanus species are found in the high -land community of Papua.

On a day-to-day basis, traditional communities of Tolikara named these species as "woromo" and "gawen". However, in general, both species have a common term, "tuke", which is used by the high-land communities in Papua. Based on variation in the morphological characteristics of the stem, leaf and the taste of fruit from both species, these species can be identified using the following keys:

- Straight Pandanus, the stem is generally bright in color, from light-brown through gray with a couple of white spots found from the bottom to the upper part, most of the leaves are straight, fruit rind is hard, taste is delicious or similar to coconut or slightly sweet (Fig. 2).... *Pandanus brosimos*
- Straight Pandanus, the stem is generally bright brown or gray, the leaves hang up through the main stem, fruit rind is not hard, the taste is not delicious or is somewhat tasteless (Fig. 3) .... *Pandanus julianettii*

***Pandanus brosimos* Merr. and perry (Pandanaceae):**

Trade name : Kelapa hutan
Local name (Papua) : Woromo (Tolikara), Tuke (high-land people)

General description: Non-woody plant, perennial, not clustering, can reach 20 m in height. The stem grows straight with an average diameter of 14-25 cm, a tap-root formation is found around the stem. The leaf is a banded shape, sword or line with size of 50-135×5-12 cm, small sharp burs are spread across the leaves' side or back. The leaves are spiral and tend cluster at the edge of the stem and branch. Flowers are usually located on the edge of a branch or under a leaf with a large protective leaf (five to seven protective leaves) with variations in size and sometimes color (green, white and yellowish). Fruit is large (20-35×15-22 cm), oval and symmetrical, the inside part of the fruit is empty or forms a tube. Small portions of fruit are formed which are numerous and rectangular and 3-4×1-1.5 cm in size. There is a single seed, 2.5×0.5 cm in size and white in color. In the growing phase, it is always associated with *Dodonaea viscosa*, *Grevillea papuana*, *Nothofagus* spp., *Pandanus julianettii*, *Pandanus conoideus* and *Bischofia javanica*.

***Pandanus julianettii* Mart (Pandanaceae):**

Traded name : Kelapa hutan
Local name (Papua) : Gawen (Tolikara), Tuke (high land people)

General description: Non-woody plant, perennial, not clustering, can reach 20 m in height. The stem grows straight with an average diameter of 14-25 cm, there is a tap-root formation around the stem. Leaves are a banded shape, sword or line, 50-135×5-12 cm in size, with small sharp burs are spread across the leaves' side or back. The leaves are spiral and tend to cluster on the edge of the stem and branch. Flowers are usually located on the edge of a branch or under a leaf

Fig. 2: Morphological characteristics of the (a) Leaf, (b) Fruit, (c) Fruit interior and (d) Stem of *Pandanus brosimos*

Fig. 3: Morphological characteristics of the (a) Fruit, (b) Separated nuts, (c) Leaf and (d) Stem of *Pandanus julianettii*

with a large protective leaf (five to seven protective leaves) of various size and are sometimes colored (green, white and yellowish). Fruit is large (20-35×15-22 cm), oval and symmetrical, the fruit interior is empty or forms a tube.

Table 1: Physical attributes and ecological conditions of both species of pandanus in the Tolikara District of Papua

Species	Latitude (m)	Slope (%)	Temperature (°C)	Humidity (%)	Shade (%)
P. brosimos	1,670-1,860	30-50	20-22	82-90	30-75 (moderate-heavy)
P. julianettii	1,670 -1,860	30-50	20-22	82-90	30-75 (moderate-heavy)

Table 2: Soil nutrient analysis of the two species of Kelapa hutan (*P. brosimos* and *P. julianettii*)

	Tested parameters							
Species	N. total (%)	N. ava. (ppm)	P. ava. (ppm)	K. ava. (per 100 g)	Mg. ava. (per 100 g)	Ph (H_2O)	C/N ratio	Organic matters (%)
P. browsimus	0.4	284.3	24.1	0.5	1.6	4.8	7.4	4.2
P. julianeti	0.4	284.3	24.1	0.5	1.6	4.8	7.4	4.2

ava: Available, ppm: Part per million, g: Gram, C/N: Carbon/nitrogen, K: Potassium, P: Phosphorus, Mg: Magnesium

Table 3: Nutrient contents of both pandanus species based on laboratory analysis

Analyzed parameters	*P. brosimos*	*P. julianettii*
Water content (%)	12.83	10.00
Ash content (%)	3.31	3.42
Fat content (g)	48.09	37.31
Total protein (g)	12.09	12.50
Fiber (g)	21.89	23.79
Vitamin C (mg)	108.43	102.54

Small portions of fruit are formed which are numerous and 3-4×1-1.5 cm in size and rectangular. There is a single seed, 2.5×0.5 cm in size and white in color. During growth, it is always associated with *D. viscosa*, *G. papuana*, *Nothofagus* spp., *P. brosimos*, *P. conoideus* and *B. javanica*.

Ecophysiological condition: No differences in the ecological and growing condition required for *Pandanus brosimos* and *Pandanus julianettii* were found in this study. Both, in general, were dominant in the latitudinal range of 1,070-1,860 m. The ideal temperature was also identical (among 20-22°C) with an average humidity ranging among 82-90% (Table 1). During the growing phase, most of the young fresh edible Pandanus are shaded by mature trees. Manual estimates indicated that 30-75% of the plants were shaded.

In general, soil from the edible Pandanus habitat was acidic (pH 4.84), with moderate levels of total N, which was available at low and moderate levels. P was available at moderate levels and Mg was observed at the same level. The C/N ratio was low, K was low and organic materials were high (Table 2).

Nutritional analyses showed there was slight various between *P. brosimos* and *P. julianettii*. of the 6 analyzed parameters (Table 3), fat (g) and vitamin C (mg) contents differed. *P. brosimos* had higher levels of fat and vitamin C compared with *P. julianettii*.

To delineate any relationships between temperature, humidity and fruit productivity, a Pearson's correlation analysis was performed using the R statistical program. The results revealed a negative correlation between temperature and fruit productivity (-0.1485), with a p-value of 0.159. A negative Pearson's correlation was found for humidity and fruit productivity (-0.1284), with a p-value of 0.225.

DISCUSSION

Botanical description: Although only two edible Pandanus species were identified in the Tolikara District of Papua, 6 variants were noted based on the traditional knowledge of the local community. Differences were observed in the size, shape, color and smell of fruit and their place of growth. These can lead to their misclassification (either variants or species), especially from the morphological insights of the traditional communities. The local communities highlighted 6 variants based on their physical appearances such as the color, size, taste of fruit and smell[25-27]. Simova *et al.*[28] acknowledged that variations in the traits of tree species traits can occur when treatments are applied differently between species. Kiang[29] indicated that color variation occurs among species and that variation is caused by the light spectra absorbed by the plants. Variation in color is possible, even within the same species. Sillitoe[30], identified several variations in a cultivar of *P. brosimos* in the Wage River West, Nipa in the Southern highlands of Papua New Guinea, whereas, in one area of the North Tari Basin, Rose[31] reported data on 17 cultivars of *P. brosimos*.

In general, several indicators exist that show the difference between the two, although both are typically common in their appearance. *P. brosimos* was bright in color, from light brown to gray, the rind of the fruit was hard, the taste was delicious or similar to coconut or somewhat sweet. While *P. julianettii* was bright brown or gray, the rind of fruit was not hard, the taste was not delicious or somewhat tasteless. French[32] noted that both species are similar in many

ways except that the leaves of *P. brosimos* are bigger and straight and do not present a bend at the top. Bourke[33] noted that *P. julianettii* is likely to have greater potential for commercialization than *P. brosimos* because the shell of the cultivated *P. julianettii* was usually easier to break. Hyndman[12] highlighted that 25-30 cultivars of cultivated *P. julianettii* are recognized and have been named within a cultivated area in Papua New Guinea.

Ecology and distribution: The distribution of Kelapa hutan (*P. brosimos* and *P. julianettii*) in Papua was limited to the high-land of Papua and Papua New Guinea, with an altitudinal range of 1,300 m[34,35]. Based on the general habitat, it was categorized as a highland plant community. It is likely that both species can adapt to the cool climate and various slope gradients (moderate to heavy) in the middle region of Papuan Island. *P. julianettii* always occurs in at elevation of 1,500-2,000 m and in the highlands, they grow as high as 2,900 m[36,12]. *P. brosimos* has a range of suitable growing altitude between 1,300 and 3,300 m with mean year-to-year precipitation of 2,000-5,000 mm[37]. *P. brosimos* was more common in the wetter parts of the Hindenburg Plateau, extending from Fugilil Mountain in the North to the Hindenburg Wall in the South of Papua New Guinea[12]. *P. brosimos* and *P. julianettii* were adaptable to growth under light shade, moderate to high intensity of shade (30-75%) with a temperature range from 18-24°C and humidity range from 80-90%. Such ideal growing conditions will accelerate the overall productivity of the edible Pandanus either in the natural habitat or in the plantations designed by the local communities. In conjunction with temperature, humidity and fruit productivity, this study revealed no clear correlation between temperature and fruit productivity ($p = 0.159$) or between humidity and fruit productivity ($p = 0.225$). Both Pearson's correlations were negative (Fig. 4). This indicates that fruit productivity did not depend on local temperature and humidity. Within the temperature and humidity ranges 20-22°C and 82-90%, respectively, productivity remained at the same frequency.

P. brosimos and *P. julianettii* were potentially productive during their growing period. Mature healthy trees growing in suitable ecological conditions were able to produce three times within a year, while less healthy trees in unsuitable ecological condition only produced once a year. In addition to their health and ecological status, age also played a pivotal role in determining fruit productivity. Trees were likely to be more productive when over 6 years of age. In this study the

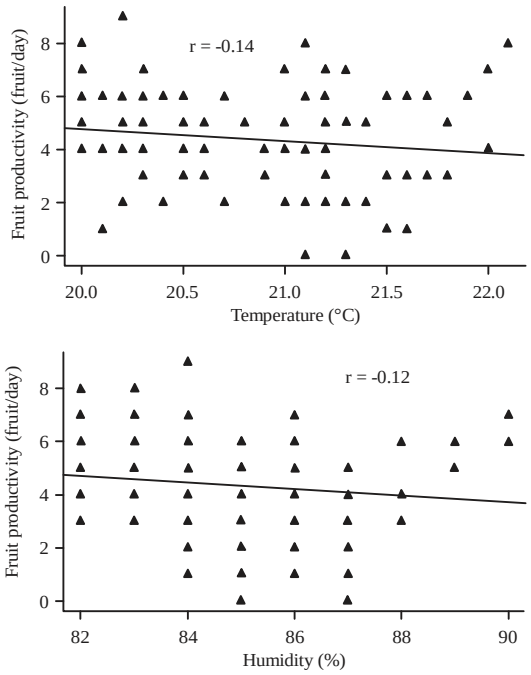

Fig. 4: Simple linear regression between temperature (20-22.1°C) and fruit productivity (0-9 fruits/day) and humidity (82-90%) and fruit productivity (0-9 fruits/day). Both correlations explained little of the measured parameters. This indicates that changes in temperature or humidity had no effect towards fruit production

average weight of a healthy fruit was about 5 kg with a diameter from 15-22 cm. Fruits varied in number with 2-4 for one fruiting period. Domesticated fruits require 2-3 months to ripen, the plant requires 7-8 years to mature and will continue bearing for 60 years[12]. Overall, during this study, day-based observations indicated that the fruit productivity was between 2 and 10 fruits. Rose[31] noted that seasonality is observed elsewhere in the New Guinea highlands, with *P. brosimos* fruiting on an annual basis and *P. julianettii* fruiting biennially[31]. However, Rose[31] favored a physiological hypothesis, such that the biennial and occasional triennial fruiting pattern of *P. julianettii* was hugely dependent on available soil nutrients, climate and the energy resources of the tree. Additionally, French[32] indicated that fruiting was seasonal and sometimes biennial for any individual branch of the tree. Ideally, the single crown of leaves on one branch of a *P. julianettii* tree only produced one cluster of nuts per season. Conversely, the particular branch from the same tree could produce many nuts every second year. It took around 5-8 years from planting to the first harvesting. *P. julianettii*

and *P. brosimos* seasonally ripened over approximately 4-6 months and became edible after June. Bourke[33] reported some crucial harvesting events that ten to follow major droughts, such as those that occurred in 1965, 1972 and 1982, although there was no information, especially on large harvesting following the primary drought in 1997.

In general, the distribution of *P. brosimos* and *P. julianeti* observed in this study was random and in some parts, tended to form clusters of atleast three to five[38]. It was different with other forest vegetation that can be found easily along with the gradient and slope in this study. Instead, they were easily found in certain areas where they grow together and were very dense. However, a handful of the edible Pandanus species were recently planted and well-managed the pre-condition habitats, soil nutrients and other ecological parameters, by local community to obtain a better yield. Beyond that, the distribution of both edible Pandanus can be found in some existed districts, such as Wamena, Habema, Tolikara and Mulia (Fig. 1).

In the present study, Pandanus (*P. brosimos* and *P. julianettii*) was found to grow well in a thin layer of soil (< 10 or ±10 cm), a moderate layer (±20 cm) and up to ≥30 cm in depth (Table 2). The ideal soil was clay with few or no rocks. However, some were found to grow well in the inundated areas, close to rivers and in swamp areas, either temporally or permanently. Habitats with thin solum soil (<10 or ±10 cm) were commonly found in the vicinity of ridge. Conversely, habitats with a moderate (±20 cm) and deep solum (≥30 m) were usually observed around foot hills and valleys in the high land region of Papua. French[32] indicated that fairly good soil fertility is needed for *P. Julianettii* to grow well, such as that found along the banks of small creeks that cover the natural hollows around the edges of hills and around the edges of small clearings in the bush. Otherwise, it bore small nuts when grown in an appropriately fertile soil such as grassland. When planted in the wetter fertile soil, it quickly developed roots and became well-established. Old trees with many branches tended to form smaller clusters of fruit due to competition among plants, therefore, pruning improved production[31,12].

Fruit nutrients: Fruits of both edible Pandanus species possessed high nutritional contents compared with other domesticated fruits[12,39,40]. The fruit contributes to the production of proteins in human and provides high amounts of nutrients. Laboratory analysis revealed that both *P. brosimos* and *P. julianettii* contain highly valuable nutrients such as proteins, vitamins, fats and fibers. The nutritional contents of both edible Pandanus are shown in Table 3. They were found to possess similar water and ash contents and total protein and fiber but not vitamin C or fat with *P. brosimos* having slightly higher levels than *P. julianettii*. Generally, both edible Pandanus had a significant amount of fat and Vitamin C compared with *Vigna radiata*, *Sorghum bicolor*, *Zea mays*, *Persea americana*, *Annona muricata*, *Lansium domesticum* and *Salacca zalacca*. Furthermore, they also contained a significant amount of provitamin A, carotenoids and fiber, which are required to maintain a healthy gut[41]. Peters[42] noted that a dried nut from the edible Pandanus has a high thiamine content and is a source of protein. In addition, Kogoya *et al.*[43] revealed it was likely that both edible Pandanus from Jayawijaya District of Papua contained high levels of the bioactive component.

The edible *Pandanus* spp. are important agricultural commodities in the high-land communities of New Guinea[34,33] and were developed to provide necessities for daily life, particularly food. These species can be consumed either fresh or preserved[44]. Rose[31] noted that the high-land community managed the in a traditional way by preserving in mud or water for temporary storage or by hanging in the rafters of houses[37]. Hyndman[12] highlighted that both Pandanus nuts do not need to be restricted in diets and can be consumed by men, women and children. Bourke[45] classified *P. brosimos* into significant and *P. julianettii* into very significant dietary commodities for communities in New Guinea.

Ethnobotany and conservation: Pandanus fruit has been consumed over generations in the high-land communities of New Guinea. Hyndman[12] noted that the Pandanus species has been pivotal to New Guinea people living at altitude of 500-3,000 m. Summerhayes *et al.*[46] revealed that New Guinea highlanders began to utilize the endemic nut of Pandanus from 49,000-36,000 years ago. Based on shared information from local inhabitants, it is found that eating habits were associated with the tradition of shifting cultivation from a high tribe in Papua. Previous cultures in Papua have referred to this process as 'nomadic'[44].

Currently, plantations of edible Pandanus are more developed by communities in the high-land of West Papua. Most of the agriculture lands are associated with the edible Pandanus in order to sustain the fruit. Several methods of agricultural land managements have been designed to permit growth in gardens including the availability of seeds surrounding mature trees or from old fruits. Schiefenhovel[47] classified *P. brosimos* and *P. julianettii* as potential domesticated plants in New Guinea. In general, the community preferred to take seeds and place them into small amounts of media before permanently growing the plants in

the garden. This represents the only conventional method used by the local community that was first performed by their ancestors. Plants in gardens are controlled and managed regularly inside fences, weeds and potential insect attacks are controlled[32]. Maintenance, including the occasional clearing of undergrowth, will regularly bear quality fruit[12]. This has been effective at providing benefits to the community in multiple ways. Due to the importance of the commodity, plantations involving families or clans through traditional ceremonies are believed will keep the land and plant in good shape. Domesticated fruits, in general, require 2-3 months to ripen and the plant requires 7-8 years to mature. The plant is able to continue bearing for 60 years[12,33]. As a comparison, Bourka[33] showed that the mean number of *P. julianettii* intended for each person is about 225 trees or 765 trees per household in the Papua New Guinea community. Therefore, there are great concerns over the intensification of edible Pandanus growth for the future sustainable management of its fruit.

Even though more than half of the edible Pandanus population is now classified as a plantation commodity, the pattern of sustain ability is still managed in a natural way. The communities did not frequently grow these plants in their gardens or on specially-managed lands. Rather, they had grown these plants with other natural forest vegetation and with little treatment. Intended treatment aimed to maximize both fruit production and the longevity of tree[33]. It can be assumed that edible Pandanus requires a high-nutrient soil and better ecological conditions to grow and produce high levels of fruit[45,33]. When grown in a garden, it is likely these species are mixed with other plantation commodities, leading to high competition for nutrients among these plants during the growing period. Furthermore, grades have also been used regularly for various plants with inferior productivity[48-51]. In addition to harvesting good-sized nuts, edible Pandanus plantations need to be maintained free of weeds[12].

It seems that the edible Pandanus has been used in cultural and ceremonial events among the communities of the high-land region in this area. The presence of a Pandanus fruit during a traditional event will provide a prestigious feel for the community. Other traditional symbols of food that should be preserved include *Pandanus conoideus* or "buah merah" and *Sus crova* or "daging babi", which present respect, cheer and meaning for events and celebrations[52,53]. Pandanus species also has been linked to the traditional election of a leader in the community who is known as a 'big man'. To attain a position within a tribe, a man should arrange and serve others traditional foods including the edible Pandanus fruit, which are sacred. In addition to the traditional ceremonies, some are often carried out annually such as prior to and after a fight, a wedding party, prior to and after agricultural harvesting and at inaugurations. When fruit stock is not available for the ceremony, people could even travel to other villages or districts for the sole purpose of purchasing it.

Habits associated with eating the Pandanus fruit in the high-land community of Papua have been passed through communities during their daily activities[46]. Information on how to yield, process and eat the fruit has been obtained from experiences and passed from parents to children. No specific method is used to manage the fruit. Traditional methods such as burning, smoking and directly eating are among the common techniques that occur across the communities. Direct assessment of the fruit's colors and physiological appearance were indicators of yield. The color of ripe fruit differs slightly to that of unripe fruit. In addition to maintaining the fruit and keeping it fresh over several days, a traditional preservation technique is to smoke it on a stove by hanging[31,33,37].

In general, the population of both species has gradually decreased over time in the high-land region of Papua. There were several factors affecting its sustain ability, such as a high frequency of consumption and other derivative utilizations, especially for housing and construction. Most of the traditional houses utilized some parts of the Pandanus plant, such as leaves and stem. Land clearing and habitat disturbance also threatened the population. Global climate change is an important threat to the edible Pandanus population over the high mountain of New Guinea[54]. Increasing temperatures, lower annual precipitation, ecological disturbances and uncontrolled harvesting, will eventually reduce the fruit productivity and endanger the long-lived existence of the edible Pandanus in the high-land of Papua.

CONCLUSION

The potential distribution of Kelapa hutan, assessed through ecological and ethnobotanical factors, was gauged using continuous-strip sampling, laboratory analyses of soil and the nutritional content of fruit, personal observations and semi-structural interviews with the local people to obtain ethnobotanical data. The results of this study indicate that the ecological conditions were suitable for the growth and production of the edible Pandanus in the Tolikara District of Indonesia New Guinea. Fruit was available throughout the year for local communities to fulfill their basic daily needs. This research confirmed that two edible Pandanus species are found in the Tolikara District: *P. brosimos* Merr. and Perry dan *P. julianettii* Mart. Based on the results of this study, it can be

concluded that Kelapa hutan plays a pivotal role in local communities through its significant contribution towards fruit nutrition and cultural identity.

SIGNIFICANCE STATEMENTS

This study revealed the potential distribution of edible Pandanus species that can be beneficial for the local communities as a pivotal agricultural commodity in the high-land of Indonesian New Guinea. These findings will help researchers to uncover the critical areas of edible Pandanus distribution and disseminate knowledge to others who are eager for it. Thus new information on the ideal geographical terrain and suitable climate conditions for the edible Pandanus can be obtained.

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