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Potential Plant Utilization in the Agroforestry System of *Tectona grandis* (Teak) and *Plukenetia volubilis* (Sacha inchi)

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Abstract. Agroforestry systems represent an approach to forest management that considers both ecological and economic functions. The system aims to optimize land use by integrating forest and agricultural components, thereby enhancing the economic and ecological benefits of the forest area. Consequently, information regarding the potential of agroforestry is essential for designing an effective management strategy. One location implementing agroforestry systems is Banyurip Village, which features an uncommon combination of key plants, namely *Tectona grandis* and *Plukenetia volubilis*. Banyurip has been selected as the research location due to its unique circumstances; most other locations primarily focus on the cultivation of sacha inchi plants, and there is a notable absence of agroforestry system applications. This presents an opportunity to explore and assess the potential benefits of integrating agroforestry practices in this area. The aims of this research is to provide information about the potential utilization of plant species present in the study area, utilizing data collection methods through interviews. Informants were selected purposively based on the criteria of farmers practicing an agroforestry system that focuses on a combination of teak and sacha inchi in production forest areas. Six farmers participated as research informants. This research was conducted in production forests managed by Perum Perhutani, employing a methodology that includes an exploratory descriptive approach accompanied by field observations and interviews. The results identified sacha inchi as the primary supporting plant species and 11 other cultivated plant species, with a total of 37 associated plant species, consisting of 10 woody plant species and 27 non-woody plant species. The identified plant types possess economic and ecological potential, such as teak, which serves as an oxygen producer, and sacha inchi, which holds significant economic value due to its oil.

Keywords: agroforestry; Banyurip village; potential benefits; sacha inchi; teak

INTRODUCTION

According to Law of the Republic of Indonesia Number 41 of 1999, a forest is a cohesive ecosystem consisting of a stretch of land rich in biological resources, primarily dominated by trees, existing in harmony with the environment, where all elements are interdependent. Indonesia is a country with a vast forest area and high biodiversity. According to Ramli, (2017), forests play a vital role in maintaining the ecological balance of the environment, serving as repositories for germplasm storage, sources of industrial timber and local sawmills, and providing income for communities surrounding the forest. Sragen Regency is one of the regions that contains both community forests and production forests.

Several forest management systems are employed to generate profits while preserving the forest's functions. One approach that emphasizes forest functionality is the implementation of agroforestry. According to Helida et al. (2021), agroforestry is one of the land management systems that can serve as a solution for addressing the consequences of land use change while simultaneously tackling food problems. In Indonesia, agroforestry began to be introduced in the late 1970, which became the forerunner of the development of agroforestry (Sardjono et al, 2003).

Agroforestry is categorized into two types: complex and simple agroforestry. (Pieter, 2022). Agroforestry encompasses various components, including agrisilviculture, agropastura, silvopastura, silvopastura, and agrosilvopastura (Hairiah et al., 2003). Based on the planting pattern, agroforestry is divided into four categories: alternate rows, alley cropping, trees along borders, and random mixture. (Naharuddin,

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2018). The application of agroforestry can provide both economic and ecological benefits. This aligns with the opinion of Prabawani et al. (2024) who stated that agroforestry, as a sustainable agricultural system with social, economic, and environmental benefits, is currently being developed on Java, the island that produces 50% of Indonesia's food. Another opinion reveals that the application of agroforestry systems in forested areas plays a crucial role in enhancing the productivity of community land use, as this will elevate economic value and improve community welfare (Samrin et al., 2024).

One of the villages that implements the agroforestry system is Banyurip Village. Through the "Lembaga Masyarakat Desa Hutan" (LMDH) Banyurip Lestari, the people of Banyurip Village have legal access to the forest land managed by Perum Perhutani. The main types of plants used in this agroforestry are teak (*Tectona grandis*) as the main plant and sacha inchi (*Pleukentia volubilis*) as the understory plant. Sacha inchi is a perennial plant that can produce eight months after harvesting (Kodahl, 2020). The selection of teak plant species is due to the research location being a forest area that produces teak wood. Sacha inchi was chosen as an agroforestry plant because of the collaboration between LMDH and private parties companies. There are various types of plants in this agroforestry system that have not been utilized optimally. Consequently, there is a necessity for research regarding the potential utilization of various plant species present in the research location. This will enable farmers to understand the potential of the flora growing within agroforestry land. It is anticipated that this information will promote the utilization of all existing plant species, particularly Sacha Inchi, and will further support the efficient and optimal management of agroforestry systems. Additionally, sacha inchi is indigenous to tropical regions and holds significant economic value, making it highly suitable for development in tropical areas like this research site.

METHODS

Research Location and Time

The research was carried out in May 2023 – June 2023 in Banyurip Village, Jenar District, Sragen Regency (Figure 1). Banyurip Village has a forest area of approximately 900 hectares. The overall topographic condition, based on its features, consists of low to medium terrain with an altitude of around 180 meters above sea level. The research site is situated on forest land that utilizes the teak and sacha inchi agroforestry system as the primary commodity.

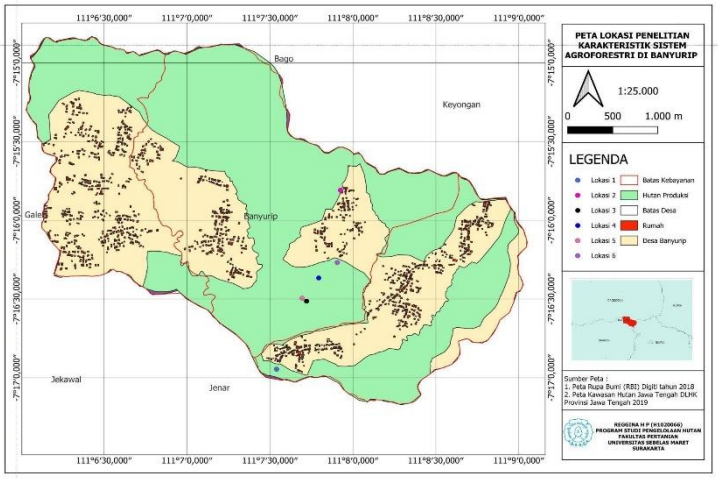

Figure 1. Research Location in Banyurip Village, Jenar District, Sragen Regency

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Data Collection

This study employs questionnaire and interview methods to gather information on plant utilization. The selection of informants was conducted purposefully, using specific criteria to identify farmers who implement agroforestry systems. The focus was on those combining teak and sacha inchi in production forest areas, a practice that has been in place since ancient times. In this study, six informants were chosen who met the established criteria. Additionally, field data collection involves exploration (recording all plant species found in the research location) and documentation techniques (taking pictures of all plant species found at the research site) aimed at enriching the understanding of the agroforestry practices applied.

Data Analysis

Data analysis in this study uses a qualitative descriptive method. Qualitative descriptive is a method for discussing data that has been collected, processed, and displayed by providing an assessment or interpretation of the data. (Alfatih, 2017). Where data obtained from the field (exploration) will be presented in percentage form to describe the actual conditions at the research location. The results of data processing are used to systematically describe the findings in the field. The data is calculated using the following formula (Well, 2021):

$$\text{Plant Family (\%)} = \frac{\sum \text{Famili of Plants}}{\sum \text{All Mention Plants}}$$

$$\text{Plant Organs (\%)} = \frac{\sum \text{Plant Organs}}{\sum \text{All Mention Plants}}$$

$$\text{Plant Processing Method (\%)} = \frac{\sum \text{Processing Methods}}{\sum \text{All Mention Plants}}$$

RESULTS AND DISCUSSION

Based on the results of the exploration, it was found that all research sites integrated the primary plant in the form of teak alongside various supporting plants in the agroforestry system. This research was conducted in six locations with varying land areas. Below is the area of land cultivated by farmers. (Table 1).

Table 1. Cultivated Land Area of Teak and Sacha Agroforestry Farmers Inches

No	Farmers	Locatian	Land area (Ha)
1.	Respondent 1	1	0.5
2.	Respondent 2	2	0.05
3.	Respondent 3	3	0.25
4.	Respondent 4	4	0.25
5.	Respondent 5	5	1
6.	Respondent 6	6	0.25

The primary supporting plant in this system is the sacha inchi. Additionally, farmers cultivate 11 diverse types of additional plants (*Maranta audinaceae, Saccharum officinarum, Morus nigra, Piper retrofractum, Amorphophallus muelleri, Coffea canephora, Manihot esculenta, Zingiber officinale, Pennisetum purpureum, Curcuma longa, Musa acuminata)*. The use of these crops aims to enhance species diversity and optimize agricultural production sustainably (Figure 2). The types of cultivated plants selected are influenced by the availability of seedlings at the research site.

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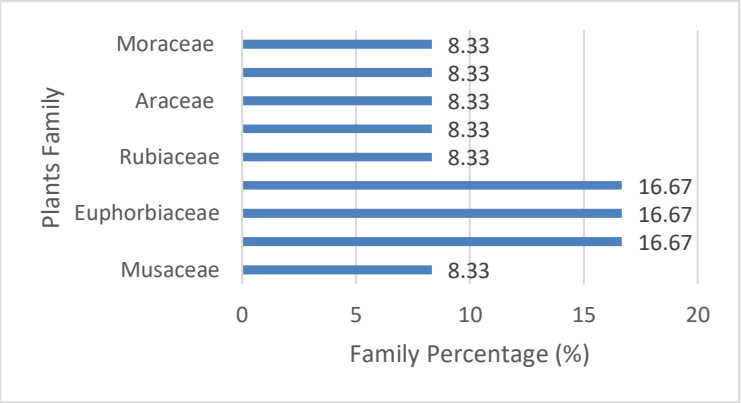

Figure 2. Histogram of Cultivated Plant Families in Teak and Sacha Inchi Agroforestry Land

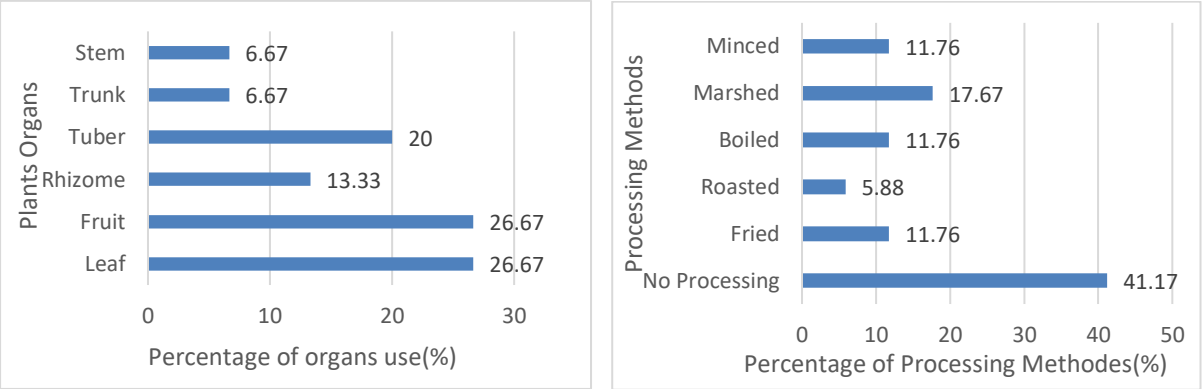

Figure 3. (a) Histogram of Plant Organ Uses; (b)Histogram of Post-Harvest Processing by farm.

The Banyurip Village community makes use of various plant organs (Figure 3a) through various processing methods, as illustrated in Figure 3b. The processing method utilized by the community is grounded in the principle of efficiency, involving minimal stages and the use of simple tools. Examples of straightforward processing methods include boiling and refining (Sada & Tanjung, 2010). In addition, some plants, such as coffee, elephant grass, sugarcane, and porang, are sold directly after harvest without undergoing any processing. Several other plant parts are also used directly, including mulberry leaves and elephant grass for animal feed, banana leaves as food wrappers, and bananas for direct consumption. In Banyurip village, goats are fed mulberry leaves, which are highly nutritious and can replace expensive concentrate feed ingredients (Yulistiyani, 2012). The decision not to process certain plant parts is influenced by farmers' practices, as they often choose to consume or sell their crops in their original state.

Agroforestry plays a significant role in carbon sequestration, as noted by Peichl et al. (2006) in Rawana et al. (2021). This highlights agroforestry's potential as an effective carbon sink and storage system, particularly due to the variety of woody plants identified in the study.Table 2. Woody vegetation exhibits a higher capacity for carbon dioxide absorption compared to other types of vegetation. This assertion is supported by the findings of Hairiah et al. (2003) noted that the proportion of vegetation types capable of storing carbon in land areas is primarily found in tree components. Moreover, the potential of agroforestry for

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carbon sequestration is enhanced by the presence of key species like teak, which, according to Ginting and Prayoga (2018), has the capacity to store carbon reserves over the long term. Several types of trees at the research site offer significant benefits. For example, eucalyptus plays a crucial role in expediting succession following ecological damage (Priswantoro et al., 2021). Additionally, lamtoro species serve as wind and fire barriers, acting as natural protectors against extreme environmental conditions such as strong winds and fires (Bachtiar & Ura, 2017).

Table 2. Potential woody plant species found in the research site

No	Scientific Name	Local Name	Potential Plant Utilization
1.	*Mangifera indica*	Mangga	As a shade Carbon absorber (Mutaqin et al., 2016)
2.	*Tectona grandis*	Jati	Oxygen Producer (Situpang, 2000 in Sulfiana, 2018)
3.	*Swietenia macrophylla*	Mahoni	As a shade because it is heat-resistant and can adapt to various types of soil (Hildasari, 2021)
4.	*Ceiba pentandra*	Randu	As an erosion barrier (Wirastuti et al., 2018)
5.	*Senna siames*	Johar	As a water-absorbing plant (Indriyani & Wulandari, 2015)
6.	*Dimocarpus longan*	Kelengkeng	As a shade (Susilo & Dhaniaputri, 2016)
7.	*Leucaena leucocephala*	Kayu putih	As a barrier to wind and fire (Bachtiar & Ura, 2017)
8.	*Muntingia calabura*	Kersen	As a shade (Saputro et al., 2022)
9.	*Melaleuca leucadendron*	Kayu putih	As an accelerator of succession (Priswantoro et al., 2021)
10.	*Calophyllum inophyllum*	Nyamplung	As an abrasion inhibitor, seawater intrusion controller, quality maintainer and windbreaker (Norsamsi et al., 2015)

In addition to woody plants, other plants were also found to have many benefits both ecologically and economically. Three types of plants were found that have ecological benefits, including elephant grass as an erosion preventer, porang to reduce erosion (Table 3).and bamboo that can withstand erosion and landslides (Table 3). Most non-woody plants found have benefits as a source of food and medicine. Such as telang flowers (Figure 4a) and mulberries that can be used as herbal tea which is currently not used by the surrounding community. However, telang flowers have been used in some locations, such as in Simonis Village, Aek Natas District, which uses telang flowers as a health drink (Ikhwan et al., 2022).

In addition, sacha inchi, as the central understory plant that makes up agroforestry, also has the potential to be developed. The people in Banyurip Village have widely utilized sacha inchi for various purposes. The use of these plants includes applications in the fields of food, health, and local economy. However, the outside community still does not know the types of sacha inchi plants and even their benefits. Even though this plant can be referred to as a "superfood". The name of sacha inchi as a superfood is closely related to the nutritional content of this plant. According to Noormansyah et al. (2023), the content owned by sacha inchi includes omega

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3, omega 6, and omega 9, which are very beneficial for intelligence. The part that has many benefits is the seeds from sacha inchi, which are processed into oil. Sacha inchi seed oil is a skincare oil that is regularly applied to maintain skin softness and health (Maya & Sriwidodo, 2022).

Table 3. Potential non-timber plant species found in the research site

No	Scientific Name	Lokal Name	Organ used	Potential Benefit of Plants
1.	*Musa acuminata*	Pisang barangan	Banana peel	Traditional medicine and crackers (Suryalita, 2019)
2.	*Curcuma longa*	Kunyit	Rhizome	As a traditional medicine that heals wounds, antibacterial, reduces intestinal motility, eliminates body odor, lowers fever, relieves diarrhea (Cahya & Prabowo, 2019)
3.	*Plukenetia volubilis*	Sacha inchi	Leaves	As animal feed (Murhofiq et al., 2022) As medicine for heart disease, arthritis, diabetes (Lourith et al., 2024)
4.	*Pennisetum purpureum*	Rumput gajah	Root	As an erosion prevention (Sakinah, 2023)
5.	*Zingiber officinale*	Jahe	Rhizome	As an anti-inflammatory, preventing skin problems, preventing cancer, improving the immune system, cold medicine, helping to lose weight, reducing nausea, detoxifying the body from toxins (Syaputri et al., 2021)
6.	*Manihot esculenta*	Singkong	Tubers	As a source of energy, treat headaches, improve digestion, treat diarrhea, treat purulent and burned wounds, treat worms, overcome rheumatism (Utama & Rukismono, 2018)
7.	*Coffea canephora*	Kopi	Trunk Fruit	As firewood As a raw material for making coffee drinks (Tnunany & Makin, 2022)
8.	*Maranta audinaceae*	Garut	Tubers	Can be processed into starch as a substitute for flour (Ilmannafian et al., 2018)
9.	*Amorphobhallus muelleri*	Porang	Tubers Root	As an ingredient for making chips (Wahyuni et al., 2020) Can reduce erosion (Septyani et al., 2023)
10.	*Piper retrofractum*	Cabe puyang	Fruit	As a traditional medicine to cure various types of diseases (Bahruddin et al., 2021)
11.	*Morus nigra*	Murbei	Leaves	Can be processed into chips and herbal teas (Isnan & Muin, 2015)
12.	*Saccharum officinarum*	Tebu	Trunk	As a raw material for making sugar (Sulistiyanto et al., 2021)
13.	*Duranta erecta*	Sinyo nakal	Fruit	As a malaria and deworming remedy (Tnunany & Makin, 2022)
14.	*Pteridophyta sp*	Paku-pakuan	Leaves	As a food source, basic materials for handicrafts, medicines, planting media for plant cultivation (Syukur, 2019)

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			Root	Helps in the formation of humus
15.	*Colocasia esculenta*	Talas	Tubers	Used as a substitute for rice or rice (Amala & Rahmawati, 2018)
16.	*Pogonatherum crinitum*	Rumput bambu	Leaves	Utilized as an antipyretic, antidiuretic, antibacterial, antitumor and hyperglycemic effect (Widayati, 2017).
17.	*Cyperus rotundus*	Rumput teki	Root	To relieve pain and normalize the menstrual cycle, hives, ulcers, bruises, as well as disorders of the gastrointestinal tract (Tania et al., 2021)
18.	*Capsicum frutescens*	Cabai rawit	Fruit	As a food preservative (Munira & Nasir, 2019)
19.	*Chindoscolus aconitifolius*	Papaya jepang	Leaves	Processed into vegetables to lower cholesterol (Maidah & Hariani, 2022)
20.	*Centrosema virginianum*	Kembang telang	Flowers	Can be processed into herbal tea (Ikhwan et al., 2022) As animal feed and food coloring (Kuswantoro & Li'ani, 2024)
21.	*Pandanus sp*	Pandan	Leaves	As a local food, traditional medicine material, building material and fiber material (Ramandey & Sembor, 2021)
22.	*Kaempferia galanga*	Kencur	Rhizome	Used as raw materials for traditional medicines, phytopharmaceuticals, cosmetics industry, food and beverage flavorings, spices, and cigarette sauce mixtures in the clove cigarette industry, can even be used as a bioinsecticide. Empirically, kencur is used as an appetite enhancer, expectorant, cough medicine, dysentery, bacterial infections, colds, stomach pain (Setyawan, 2013)
23.	*Bambusa sp.*	Bambu	Shoot	Used as a food ingredient Used as a household craft and musical instrument (Pusat Pengendalian Pembangunan Ekoreligion Kalimantan, 2017)
			Root	Helps resist erosion and landslides Filters and neutralizes pollutants that enter the soil (Pusat Pengendalian Pembangunan Ekoreligion Kalimantan, 2017)
24.	*Psidium guajava*	Jambu biji	Leaves	Used as a remedy for diarrhea, and bloating (Nuryani, 2017)
25.	*Imperata cylindrica*	Ilalang	Leaves	As a medicine for deep heat Komansilan & Rumondor, 2022)
26.	*Gliricida sepium*	Gamal	Leaves	Feed (Nurfaizin & Matitaputty,

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Figure 4. (a) Telang flowers; (b) Sacha inchi nuts

The plant species that make up the agroforestry system show varying economic potential, as outlined in Table 4.. The highest economic potential is in sacha inchi seed oil, which has a market price in e-commerce of Rp. 176,400/250 mL. The price reflects the added value of sacha inchi seed oil, which is known as a superfood due to its excellent nutritional content. In addition to sacha inchi, other plant species in agroforestry systems also show promising economic value, as described in Table 4 based on interviews and market prices. Types of non-timber plant products can be a significant source of income for the community (Agustina et al., 2024).

Figure 5 shows the sacha inchi oil produced by the LMDH Banyurip Lestari, which has a high economic value. Through the research, it is hoped that the utilization of the agroforestry system can be optimal. So that the benefits obtained by farmers are greater, especially in the economic field. The findings of this study indicate that an agroforestry system combining teak and sacha inchi provides a range of ecological and financial benefits. These advantages suggest that the system has the potential to be applied in other areas with similar biophysical and socio-economic characteristics, to support land sustainability and improve the welfare of farmers in the region.

Figure 5. Sacha inchi oil processed products by LMDH Banyurip Lestari

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Table 4. Economic potential of non-timber plant species found in the research site

No	Local Name	Organs used	Price	
			Raw	Product
1.	Pisang barangan	Banana peel	-	Rp. 28.000/Kg (Banana peel powder)
		Fruit	25.000/Bunch	-
		Leaves	6.500/Kg	-
2.	Kunyit	Rhizome	15.900/Kg	Rp. 28.000/Kg (Turmeric powder)
3.	Sacha inchi	Leaves	-	-
		Fruit	5.000-7.500/Kg	
		Seed	-	176.400/250 Ml (Oil)
4.	Rumput gajah	Leaves	25.000/Bunch	
5.	Jahe	Rhizome	38.000/Kg	30.000/500 gram
6.	Singkong	Tubers	7.999/Kg	29.000/kg (Cassava chips)
7.	Kopi	Fruit	90.000/Kg (Green bean)	
8.	Garut	Tubers	20.000/Kg	27.200/Kg (Garut flour)
9.	Porang	Tubers	24.700/Kg	62.350/280 gram (Porang rice)
10.	Cabe puyang	Fruit	44.995/250 gram (Dry)	-
11.	Murbei	Leaves	6.000/50 Sheets	77.900/Kg (Mulberry leaf tea)
		Fruit	26.900/Kg	-
12.	Tebu	Trunk	-	-
13.	Sinyo nakal	Fruit	10.500/Kg	-
14.	Paku-pakuan	All parts	5.000/5-7 Rod	-
15.	Talas	Tubers	12.000/Kg	15.000/250 gram (Chips)
16.	Rumput teki	Root	7.000/100 gram	-
17.	Cabai rawit	Fruit	15.900/500 gram	-
18.	Papaya jepang	Leaves	7.500/100 gram	-
19.	Kembang telang	Flower	30.000/100 gram (Dry)	35.040/50 gram (Telang flower tea)
20.	Kencur	Rhizome	29.000/Kg	13.500/Kg (Kencur Powder)
21.	Bambu	Shoot	16.500/500 gram	-
		Trunk	15.00/Rod	-
22.	Jambu biji	Leaves	5.880/100 gram	-
		Leaves	22.000/Kg	-
23.	Gamal	Leaves	5.880/100 gram	-

CONCLUSION

This research can be concluded if 37 plan types make up the teak and sacha inchi agroforestry system. The various plant species have amazing benefits, both in terms of ecology and economy. Ecologically, these plants support environmental balance by improving soil fertility, providing habitat for various organisms, and assisting in the water and carbon cycle. Economically, these plants

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have economic value as raw materials, food, feed, and a source of additional income for local communities. This combination of plant species diversity reflects the potential for optimizing the function of agroforestry in creating a sustainable system. Understanding the potential and benefits of these plants is expected to help communities optimize their use for welfare and environmental sustainability, as well as develop more efficient and profitable economic strategies.

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