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Etnobotanical Study of Medicinal Plants by the Community Pucung Village, Kismantoro District, Wonogiri Regency, Central Java

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Abstract. *Indonesia is known as a living laboratory because its forests host approximately 30,000 plant species, of which around 9,600 are medicinal. The benefits of natural medicines derived from plants have been empirically proven, encouraging communities to preserve them. The use of medicinal plants by communities reflects the relationship between humans and plants, known as ethnobotany. This relationship can show how the community of Pucung Village uses medicinal plants, the efforts and conservation status of the medicinal plant species found, and the community's perceptions of medicinal plants and the sustainability of local knowledge about their use for future generations. Using an ethnobotanical approach, this study focuses on local wisdom as the foundation for preserving knowledge of medicinal plants in Pucung Village. The data collection methods used were purposive sampling and snowball sampling. Using these techniques, 18 informants were identified. Based on the interview results, 56 plant types from 30 families were identified, with turmeric (100%) being the most frequently used. The plant part with the highest percentage was leaves (45.16%). The most dominant processing method was boiling (37.70%). The primary source of plant acquisition was cultivation activities (49.30%). The most common plant habit was herbaceous (37%). There are 24 medicinal plant species classified as least concern, 9 as data deficient, and 23 as not evaluated. Efforts to sustain local knowledge include direct practice and the transmission of knowledge through oral communication. Nine informants tend to use medicinal plants to maintain physical health, while nine others tend to prefer using medicinal plants first.*

Keywords: *conservation, ethnobotany, local knowledge, pucung village*

Citation
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INTRODUCTION

Indonesia is called a "living laboratory" because it hosts around 30,000 plant species with unique features and benefits (Harmanto & Ahkam, 2007). Among the 30,000 plant species, approximately 9,600 species of medicinal plants are found throughout Indonesia (Emilda et al., 2017). Examples of medicinal plant use include brotowali, used to treat fever, and cengkodok leaves, used as an external medicine for wounds (Gunadi et al., 2017). The utilization of medicinal plants as raw materials for herbal medicines offers health benefits to the community (Sari et al., 2015). According to research by the World Health Organization (WHO), more than 80% of developing countries worldwide use medicinal plants to treat various diseases (Ali et al., 2022). Medicinal plants have several advantages, including relatively minor side effects when used appropriately. However, they also have disadvantages related to their mode of action, which targets the source of the disease and improves the body's overall system, making them less suitable for emergency use (Herbie, 2015).

The community's use of medicinal plants illustrates the relationship between humans and plants, a field of study known as ethnobotany. Ethnobotany is a botanical study that examines the mutual relationship between humans and plants, focusing on the utilization of plants for cultural purposes and the preservation of natural resources (Dharmono, 2007). This preservation can be achieved by disseminating knowledge about the processing, use, and efficacy of medicinal plants (Haryono et al., 2014).

The use of medicinal plants by local communities is a valuable form of local wisdom and therefore needs to be studied more deeply to ensure the sustainability of the culture of medicinal plant use. Local knowledge, often referred to as the knowledge of rural people, is the collective knowledge possessed by a population, communicated orally, holistic in nature, and highly vulnerable to extinction (Iskandar & Iskandar, 2017). Research on the community's use of medicinal plants is conducted to determine the types used, their uses, plant parts, habitus, and sources (Rahmatika et al., 2024). Another important aspect to research is how local communities maintain the sustainability of knowledge about medicinal plants and the sustainability of medicinal plants themselves (Silalahi et al., 2021; Ulfa et al., 2024). To sustain the culture of using medicinal plants, it is essential to introduce medicinal plants and their characteristics, thereby properly disseminating knowledge of their benefits. The activity can be initiated by identifying medicinal plants used explicitly by the local community (Hamzari, 2008).

Pucung Village is one of the villages in Wonogiri Regency, Central Java, where the community continues to utilize medicinal plants. This is reinforced by the statement of one of the village officials, who said that the use of medicinal plants by the local community is still ongoing. The use of medicinal plants has been practiced from generation to generation, thereby forming a relationship between humans and their environment, commonly referred to as Traditional Ecological Knowledge (TEK) (Berkes et al., 1994). Based on this information, an ethnobotanical study of medicinal plants in the Pucung Village community will be conducted. This

study aims to determine the types and uses of medicinal plants by the community, and how local communities maintain and pass on information about their use to the next generation in Pucung Village.

MATERIALS AND METHODS

A. Location and Time Research

The research was conducted from August to October 2024, located in Pucung Village, Kismantoro District, Wonogiri Regency, Central Java (Figure 1). Pucung Village comprises four hamlets: Pucung, Jladri, Gupakan, and Gandring.

B. Data Collection Method

The research began with a site survey and the identification of interviewees. The interview techniques employed included purposive sampling and snowball sampling. Purposive sampling was used to identify key informants based on specific characteristics, while snowball sampling was employed to expand the informant network, thereby yielding more diverse data. The characteristics of informants used in this study are (1) residents of Pucung Village, Kismantoro Subdistrict, who are knowledgeable about herbal medicine, such as herbal medicine makers, or (2) general residents of Pucung Village who frequently use herbal medicine, or (3) village elders. Primary data were collected through interviews and observations, while secondary data were obtained from literature reviews. The tools used in this research were a voice recorder, questionnaires, stationery, a camera, and tally sheets. The subjects observed in this study were the people of Pucung Village.

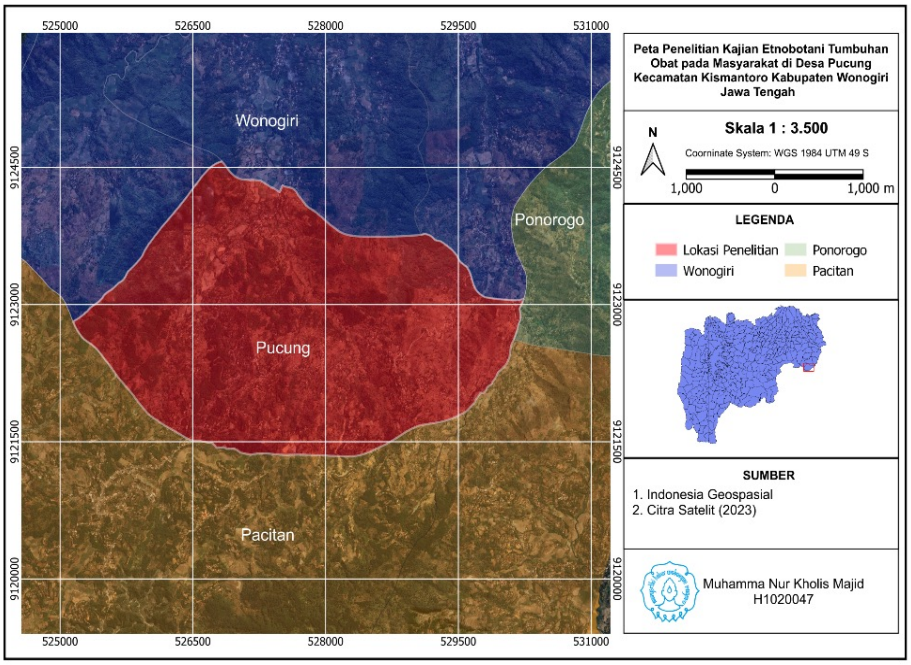

Figure 1. Research Location

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C. Data Analysis Method

This research employs a combination of research methods, commonly referred to as mixed methods. The mixed-methods design used in this research is concurrent triangulation (a balanced mixture of quantitative and qualitative methods). Data analysis in this research uses descriptive analysis. Descriptive data analysis is conducted to provide a clearer understanding of the social situations at the research site. Descriptive research is also conducted to explore and clarify specific social phenomena or realities.

1. Qualitative Analysis

Quantitative analysis in this study was used to find the percentage of medicinal plant types, plant parts, methods of utilization, sources of acquisition, and plant habit. The obtained data were then processed using the following formula (Utomo, 2017).

2. Quantitative Analysis

Quantitative analysis in this study was used to find the percentage of medicinal plant types, plant parts, methods of utilization, sources of acquisition, and plant habitus. The obtained data were then processed using the following formula (Utomo, 2017):

Percentage of medicinal species =
(Σ plant species)/(Σ number of respondents)×100%

Percentage of plant organ=
(Σ plant organ)/(Σ number of plant organ)×100%

Percentage of methods processing=
(Σ plant processing)/(Σ number of methods processing)×100%

Percentage of source=
(Σsource medicinal plant)/(Σnumber of source)×100%

The calculation of the percentage of habitus refers to the formula used by Sukmawati and Yuniati (2013):

Percentage of habitus=
(Σhabitus in plant species)/(Σ type of plants)×100%

3. Data Validation

Qualitative data validity in this study is achieved through triangulation. Testing data validity through triangulation involves checking data across multiple sources in different ways. Triangulation in this study employs three types of triangulation: source, techniques/methods, and time.

a. Source triangulation

Triangulation of sources is conducted to test the credibility of data by verifying the same information across multiple sources or informants using the same data collection techniques. If there are differences in the data results, they may be due to differences in the sources' perspectives. In this case, the researcher will conduct further discussions (member checks) or collect data from other sources to achieve the highest possible data validity.

b. Technical triangulation

Technical triangulation was used to test the data's credibility by verifying the same information across different data collection techniques. For example, data from interviews on the types of medicinal plants used by the community in their yards were verified through direct field observation. In addition, confirmation of the benefits of these types of plants was ensured by referring to literature and competent sources.

c. Time triangulation

The validity of data in temporal triangulation is determined by the time of data collection. Data collected when the informant is in an optimal condition (ready state) tends to be more valid. Furthermore, validity can be strengthened by repeated data collection from the same informant.

D. Plant Conservation Status

The conservation status of medicinal plants in this study was determined by

examining the types of plants reported in the literature used during the study. The literature used is the IUCN Red List, CITES Appendix, and the Minister of Environment and Forestry Regulation No. P.106 of 2018. Classification based on the IUCN Red List to determine the conservation status of medicinal plant species and CITES to determine whether these medicinal plant species can be traded or not by exploring the official websites of IUCN and CITES (Mansari et al., 2023).

RESULTS AND DISCUSSION

A. Characteristic of Informants

According to the interview results, 18 informants were from four hamlets: Pucung, Jladri, Gupakan, and Gandring (Figure 1). The majority of informants worked as farmers (44%). The majority of informants had a high school education (39%) and an elementary school education (28%). The average age of the informants fell within the productive category (15-64 years), with the majority being male (78%).

B. Types of Medicinal Plants Used

Based on interviews with 18 informants, 56 plant species from 30 families were identified as being used by the people of Pucung Village. The most widely used plants are those from the Zingiberaceae family. There are 10 types of medicinal plants in the Zingiberaceae family, six types of medicinal plants in the Fabaceae and Euphorbiaceae families, and three types of plants in the Apiaceae family. The large number of plant species in the Zingiberaceae family is influenced by the types of plants cultivated by the community, which have high economic value. Zingiberaceae, commonly known in Indonesia as ginger plants, are perennial herbs characterized by their rhizomes, which contain aromatic compounds. The rhizomes of Zingiberaceae contain essential oils and alkaloids that can be used as medicine. Zingiberaceae grow well in forests and subtropical areas. Zingiberaceae can thrive in a wide range of environments, from lowlands to highlands at elevations exceeding 2,000 meters above sea level in areas with high rainfall. The village of Pucung itself is located in a hilly region with steep slopes, a tropical climate, and an elevation of 650 meters above sea level. The community's use of a medicinal plant can serve various purposes. This finding aligns with research by Azzahra et al. (2024) and Rahmatika et al. (2024), which identified the Zingiberaceae family as the most widely used among medicinal plants by the community. These various uses can illustrate the level of dependence and the community's activity in using the plant. Several percentages of medicinal plant use by informants are shown in Figure 2.

The percentage of medicinal plants used can illustrate the usefulness of a plant for informants. The percentage indicates the number of informants who use the plant. Among the medicinal plants used by the people of Pucung Village, turmeric (*Curcuma longa*) is the most widely used, with a usage rate of 100%. The community widely uses turmeric for its numerous medicinal benefits. Interviews with informants revealed that turmeric has several benefits, including relieving sore throats, stomach ulcers (gastritis), menstrual pain, and boosting the immune system. In addition to its benefits, turmeric has a relatively high economic value and is one of the tolerant species alternatives that can survive under the stand canopy (Atmanto et al., 2023).

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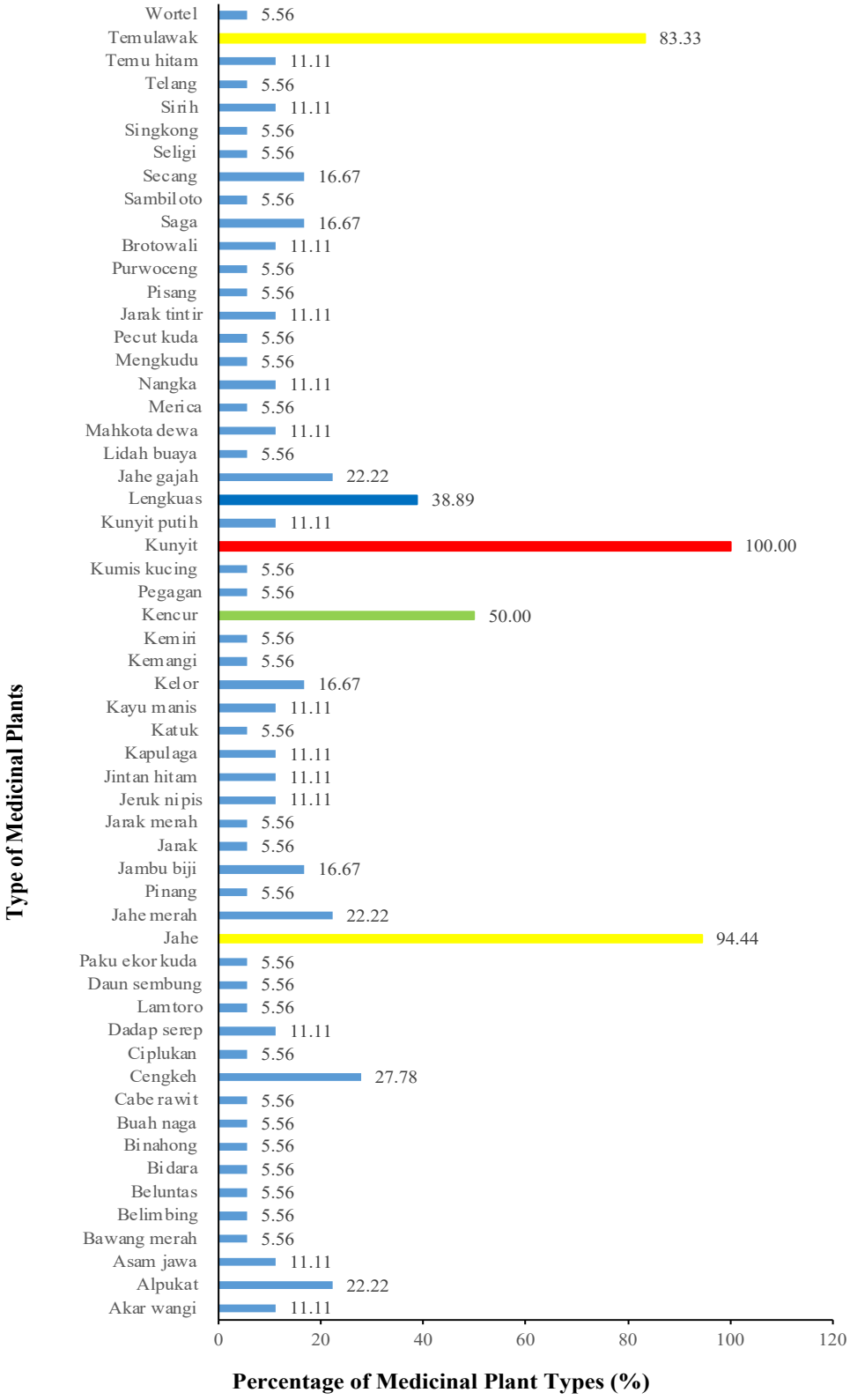

Figure 2. Percentage of utilization of medicinal plant species used by informants

Table 1. Types of diseases treated

No.	Disease	Type of Medicinal Plant
1.	Respiratory Disorders & Allergies (Asthma, Cough, Flu, Sore throat, Hives, and Itching)	*Curcuma zanthorrhiza, Zingiber officinale, Zingiber officinale var.* Rubrum*, Zingiber zerumbet, Biancaea sappan, Kaempferia galangal, Citrus aurantiifolia, Piper nigrum, Allium cepa, Curcuma longa, Curcuma zedoaria, Stachytarpheta jamaicensis, Cinnamomum burmannii, Tinospora cordifolia*
2.	Digestive Disorders (Diarrhea, Ulcer, Thrush, Digestive tract, Appetite, Jaundice)	*Curcuma zedoaria, Psidium guajava, Stachytarpheta jamaicensis, Kaempferia galanga, Curcuma longa, Areca catechu, Curcuma zanthorrhiza, Abrus precatorius, Tamarindus indica, Persea americana, Citrus aurantiifolia, Piper nigrum, Jatropha gossypiifolia, Artocarpus heterophyllus, Averrhoa carambola, Hylocereus polyrhizus, Tinospora cordifolia, Curcuma aeruginosa*
3.	Common Infectious & Inflammatory Diseases (Fever, Tinea versicolor)	*Erythrina variegate, Andrographis paniculata, Stachytarpheta jamaicensis, Alpinia galanga*
4.	Cardiovascular & Metabolic Diseases (Diabetes, Hypertension, Heart, Cholesterol, Stroke)	*Physalis angulata, Nigella sativa, Musa paradisiaca, Andrographis paniculata, Blumea balsamifera, Piper betle, Orthosiphon aristatus, Clitoria ternatea, Moringa oleifera, Morinda citrifolia, Manihot esculenta, Nigella sativa*
5.	Musculoskeletal Disorders (Rheumatism, Sciatica, Period pain, Sprained, Headache)	*Stachytarpheta jamaicensis, Jatropha gossypiifolia, Morinda citrifolia, Cinnamomum burmannii, Moringa oleifera, Alpinia galanga, Zingiber officinale, Zingiber officinale var. Rubrum, Zingiber zerumbet, Phaleria macrocarpa, Nigella sativa, Equisetum ramosissimum, Centella asiatica, Andrographis paniculata, Ziziphus mauritiana, Piper betle, Curcuma longa, Phyllanthus buxifolius, Abrus precatorius*
6.	Skin Disorders (Wounds)	*Anredera cordifolia, Physalis angulate, Stachytarpheta jamaicensis, Leucaena leucocephala, Jatropha curcas, Jatropha multifida, Aloe barbadensis*
7.	Specific Organ & System Problems (Kidney, Cancer)	*Curcuma zanthorrhiza, Morinda citrifolia*
8.	Common Health Problems & Treatments (Cold)	*Zingiber officinale, Zingiber officinale var. Rubrum, Zingiber zerumbet,*
9.	Health & Beauty (Eye health, Oral health, Hair)	*Daucus carota, Piper betle, Ocimum basilicum, Aleurites moluccana, Sauropus androgynous, Aloe barbadensis,*
10.	Health & Vitality (Memory, Endurance, Lose weight, Impotence)	*Centella asiatica, Chrysopogon zizanioides, Hylocereus polyrhizus, Syzygium aromaticum, Citrus aurantiifolia, Elettaria cardamomum, Curcuma longa, Curcuma zedoaria, Artocarpus heterophyllus, Pimpinella pruatjan, Tamarindus indica*
11.	Boost breastfeeding	*Curcuma zanthorrhiza, Pluchea indica, Sauropus androgynus*

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According to Table 1, the medicinal plants used by the people of Pucung Village can treat 36 different diseases, grouped into 11 categories. The efficacy of these medicinal plants is based on information obtained from interviews with informants. Medicinal plants from the Zingiberaceae family are the most commonly used plants by the people of Pucung Village. Various types of medicinal plants offer benefits for treating multiple diseases. For instance, ginger can be used to treat colds, coughs, and muscle aches. This is consistent with Kuntorini's (2005) research, which states that the Zingiberaceae family is used as a remedy for coughs, headaches, and muscle aches, and is also rubbed on the body. The family is made into a paste (in the form of a powdered paste) for treating muscle aches among the Javanese and Banjar ethnic groups in Kalimantan.

C. Utilized Plant Organ

Based on interviews with informants, the organs of plants used as medicine by the people of Pucung Village include bark, wood, leaves, flowers, roots, tubers, rhizomes, fruits, seeds, and sap. Based on Figure 2, the organ of the plant most commonly used by the community is the leaf. All plant parts possess therapeutic properties that can treat various diseases. The flower, seed, and bark portions have potential as antimicrobial, antioxidant, and anticancer agents (Donga & Chanda, 2020). The percentage of plant organs used by the community for medicinal purposes is shown in Figure 3.

Based on Figure 3, the leaf is the part of the plant that is most commonly used by the community. The leaf accounts for the highest percentage at 45.16%, followed by the fruit at 16.13% and the rhizome at 14.52%. Leaves are the most frequently utilized plant part by the community as they are considered easier to find and more efficient (Azzahra et al., 2024). This ease of collection and processing makes leaves a preferred choice across various ethnic communities (Nguyen et al., 2019). According to Handayani (2003), leaves are the most widely used plant organs for treatment due to their high water content (70–80%) and their role as the site of photosynthate accumulation, which is suspected to contain organic substances capable of curing diseases. Every part of the plant has medicinal benefits. All parts of the plant, including leaves, fruits, flowers, stems, roots, seeds, and bark, are known to possess therapeutic properties that can help treat various diseases.

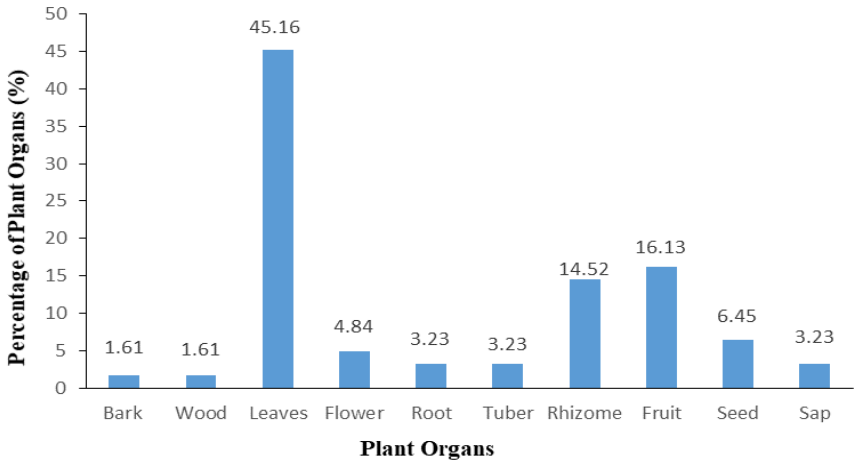

Figure 3. Organ of plants used as medicine

D. Processing Method of Medicinal Plants

The use of plants as medicine requires proper methods for processing and using them to maximize their benefits. The processing methods used are based on the local community's knowledge of medicinal plants. Several methods of processing medicinal plants used by the community are illustrated in Figure 4.

Based on Figure 4, several processing methods are used by the people of Pucung Village. These processing methods include no processing, pounding, boiling, cooking, and brewing. The most dominant processing method used by the local community is boiling (39.34%). Twenty-four types of plants can be processed by boiling. Of the 24 plant types processed by boiling, 18 (75%) use their leaves. The boiling process is done to reduce membrane permeability, allowing compounds to be released more effectively. The community also believes that boiled plant organs are more effective and their benefits are more noticeable because the compounds from the boiled organs are released and mix with the boiling water. Several plant species are utilized without any processing. Utilization without processing refers to direct methods of using medicinal plants, such as applying, rubbing, or consuming them without any processing.

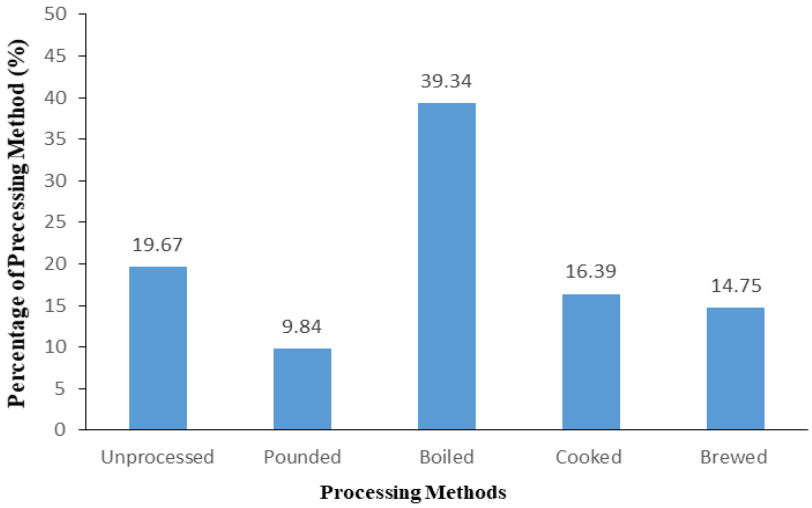

Figure 4. Methods of processing medicinal plants

E. Sources of Medicinal Plants

The interviews showed that the sources of medicinal plants for the people of Pucung Village included wild (natural), cultivated, and purchased plants. The percentages of medicinal plant sources are shown in Figure 5. The results of the calculation of the percentage of medicinal plants indicate that the community obtains more medicinal plants from cultivation, with a 48.61% share. The majority of the community's livelihood is as farmers, which leads them to use vacant land around their homes and in their gardens to cultivate medicinal plants. The community cultivates several types of medicinal plants, especially ginger. These plants are often cultivated because they have market value that benefits the community's economy, especially for farmers.

The community's cultivation activities are carried out in community forests using an agroforestry system. The forms of agroforestry found are mixed gardens and home gardens. The presence of multiple components within

this system can influence social, economic, and ecological sustainability. The use of various types of commodities ensures that farmers do not depend on a single harvest. This makes conservation practices more economically resilient and reduces farmers' incentives to overexploit the forest. Furthermore, the community's traditional ecological knowledge regarding the interaction between plants and the environment can be passed down from generation to generation, which is a vital aspect of cultural and knowledge conservation.

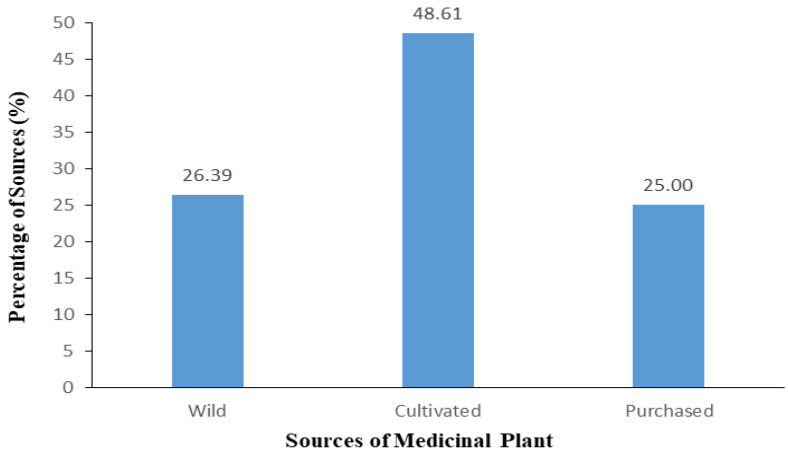

Figure 5. Sources of Medicinal Plants

F. Habitus of Medicinal Plants

Based on their habitus, the medicinal plants used by the people of Pucung Village can be categorized into five types: shrubs, bushes, trees, herbs, and vines (Figure 6). Figure 6 indicates that the highest percentage of plant habitus is herbaceous plants at 39%, followed by tree habitus at 25%, shrub habitus at 20%, liana habitus at 11%, and bush habitus at 5%. Based on the above results, the most widely utilized medicinal plant habitus is the herbaceous plant. Herbs have strong vitality and high adaptability to surrounding plants. Their strong vitality and high adaptability to the surrounding environment enable herbaceous plants to grow in a wide range of habitats, including moist or waterlogged soil, dry soil, rocky terrain, and habitats with dense shade.

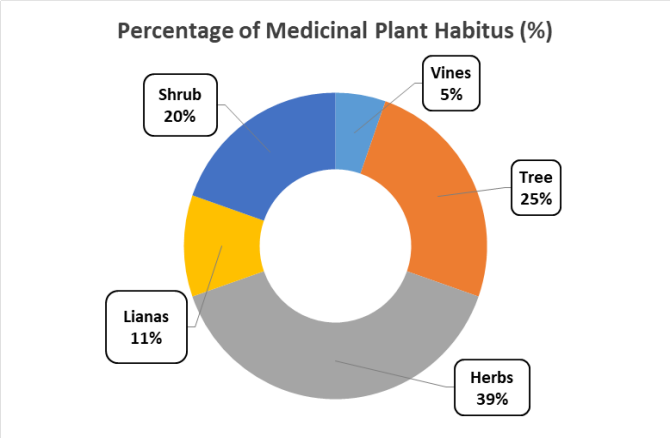

Figure 6. Habitus of Medicinal Plant

G. Status and Conservation Efforts for Medicinal Plant Species

According to research on the IUCN Red List website, 24 medicinal plant species used by the community are classified as 'least concern', nine as 'data deficient', and 23 as 'not evaluated'. The conservation status of medicinal plants found in Pucung Village is presented in Table 2. A search of LHK Regulation No. 106 of 2018 and CITES has also been conducted. However, none of the medicinal plants found in Pucung Village are listed on the website or in the ministerial regulation. Based on the results (Table 3), the medicinal plants identified are still considered safe for use, both in terms of conservation and species abundance in nature. However, this should not be used as an excuse for the community to exploit medicinal plants. Conservation efforts for medicinal plants should also be implemented through cultivation. Cultivating medicinal plants not only helps preserve species but also supports the community's need for traditional medicines.

Table 2. Conservation Status of Medicinal Plant

No.	Conservation Status IUCN Category	Common name of plant species
1.	Least concern	Secang, temu hitam, asam jawa, mengkudu, wortel, kelor, jambu biji, kemiri, dadap serep, lamtoro, seligi, sembung, jarak tintir, mahkota dewa, alpukat, ciplukan, kayu manis, paku ekor kuda, bidara, pinang, jarak merah, jarak pagar, pecut kuda, pegagan
2.	Data deficient	Jahe, jahe merah, jahe gajah, temulawak, kencur, kunyit, kunyit putih, singkong, belimbing
3.	Not evaluated	Sirih, buah naga, kemangi, jeruk nipis, sambiloto, lengkuas, merica, bawang merah, nangka, lidah buaya, kumis kucing, cengkeh, saga, brotowali, kapulaga, jintan hitam, akar wangi, telang, binahong, beluntas, katuk, purwoceng, pisang

H. Sustainability of Local Knowledge of Medicinal Plants

Knowledge of traditional medicine is increasingly eroded by foreign cultures and modernization (Ledo & Seran, 2019). The role of parents in disseminating information is crucial to preserving the cultural heritage of medicinal plant use. Based on the study's results, all informants expressed a desire to pass on their knowledge of medicinal plants to the younger generation; however, the community has yet to find the most effective way to do so. The influence of modernization is based on the consideration that treatment using medicinal plants generally requires a longer time compared to chemical (modern) drugs, especially for chronic diseases such as stroke, cancer, heart disease, and diabetes.

Nevertheless, the community has made some efforts to preserve this knowledge. These efforts include direct practice and the transmission of knowledge to the younger generation through oral communication. The transmission of information to the younger generation often takes place at home. According to the interviews, information is transmitted when a family member is sick, and medicine is made from plants. In this regard, one informant mentioned that: “I taught it from my mother. So, when a family

member is sick, for example, if someone has rheumatism, we boil red ginger and use it to make a vegetable dish. So I will pass this knowledge on to my children as well".

Additionally, the involvement of the younger generation in the direct practice of preparing traditional herbal remedies can help sustain local knowledge of medicinal plants. Local knowledge of medicinal plants can also be lost if elders who possess it do not pass it on to the younger generation. In this regard, one informant mentioned that: "In making herbal medicine, I have group members, some of whom I have trained and involved directly in the process. So, indirectly, they will also learn from it".

Public Perception of Medicinal Plant Use

Knowledge of medicinal plants is passed down from generation to generation, and their benefits can be felt when used appropriately and in the correct dosage. Based on the interview results, informants believe that medicinal plants can cure certain diseases (the efficacy of medicinal plants can be seen in Table 1). The interview results indicate that nine informants tend to use medicinal plants to maintain their physical health and as a supplement to conventional medication. This is based on the consideration that treatment with medicinal plants generally requires more time compared to chemical drugs, especially for chronic diseases such as stroke, cancer, heart disease, and diabetes. However, all nine informants still choose to consult a doctor first if they experience illness. The interview results also showed that nine other informants tended to prefer using medicinal plants first, but would switch to chemical drugs if they did not see significant effects. The community generally uses medicinal plants first for mild illnesses that do not require direct medical intervention.

Several factors encourage people to use medicinal plants. The first is cultural factors, which significantly influence decision-making. The community's use of medicinal plants has become a tradition passed down from one generation to the next (Jennifer & Saptutyningsih, 2015). This tradition not only reflects the nation's cultural heritage but also plays a crucial role in maintaining the sustainability of herbal medicine use. Another factor is income. People with high incomes tend to seek treatment from doctors or hospitals. In contrast, those with low incomes initially use medicinal plants to alleviate symptoms of illness and, if the condition does not improve, switch to medical treatment (Fransiska et al., 2022). Research conducted by Jannah et al. (2021) shows a correlation between income and the public's decision to use TOGA (Tanaman Obat Keluarga). However, this phenomenon requires further in-depth research, as many factors influence the public's consideration of using medicinal plants.

CONCLUSION

There are 56 plant species from 30 families used by the people of Pucung Village, with turmeric (*Curcuma longa*) being the most commonly used medicinal plant, accounting for 100%. The plant parts most commonly used for medicinal purposes are: leaves (45.16%), fruits (16.13%), rhizomes (14.52%), seeds (6.45%), flowers (4.84%), roots (3.23%), tubers (3.23%), sap (3.23%), wood (1.61%), and bark (1.61%). Several processing methods are employed, including no processing (19.67%), pounding (9.84%), boiling (37.7%), cooking (18.03%), and steeping (14.75%). Some sources of medicinal plants include wild (natural) (25.35%), cultivated (49.3%), and purchased (25.35%).

Some of the highest percentages of plant habitus are herbs (39%). There are 24 types of medicinal plants used by the community that fall into the least concern category, nine types fall into the data-deficient category, and 23 types fall into the not evaluated category. The continuity of local knowledge about medicinal plants is preserved through direct practice, oral transmission to younger generations, and its incorporation into the student learning curriculum, including in policy-making for local governments.

AUTHOR CONTRIBUTION

M.N.K.M. Designed the research, conducted the research, collected and analyzed the data, **A.A.** Designed the research, wrote the manuscript, and provided direction in writing the article. **R.L.W.** Wrote the manuscript, provided direction in writing the article.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest regarding the publication of this manuscript. The research was conducted and reported with full adherence to ethical standards, ensuring there were no financial or personal conflicts that could have influenced the results or interpretation.

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