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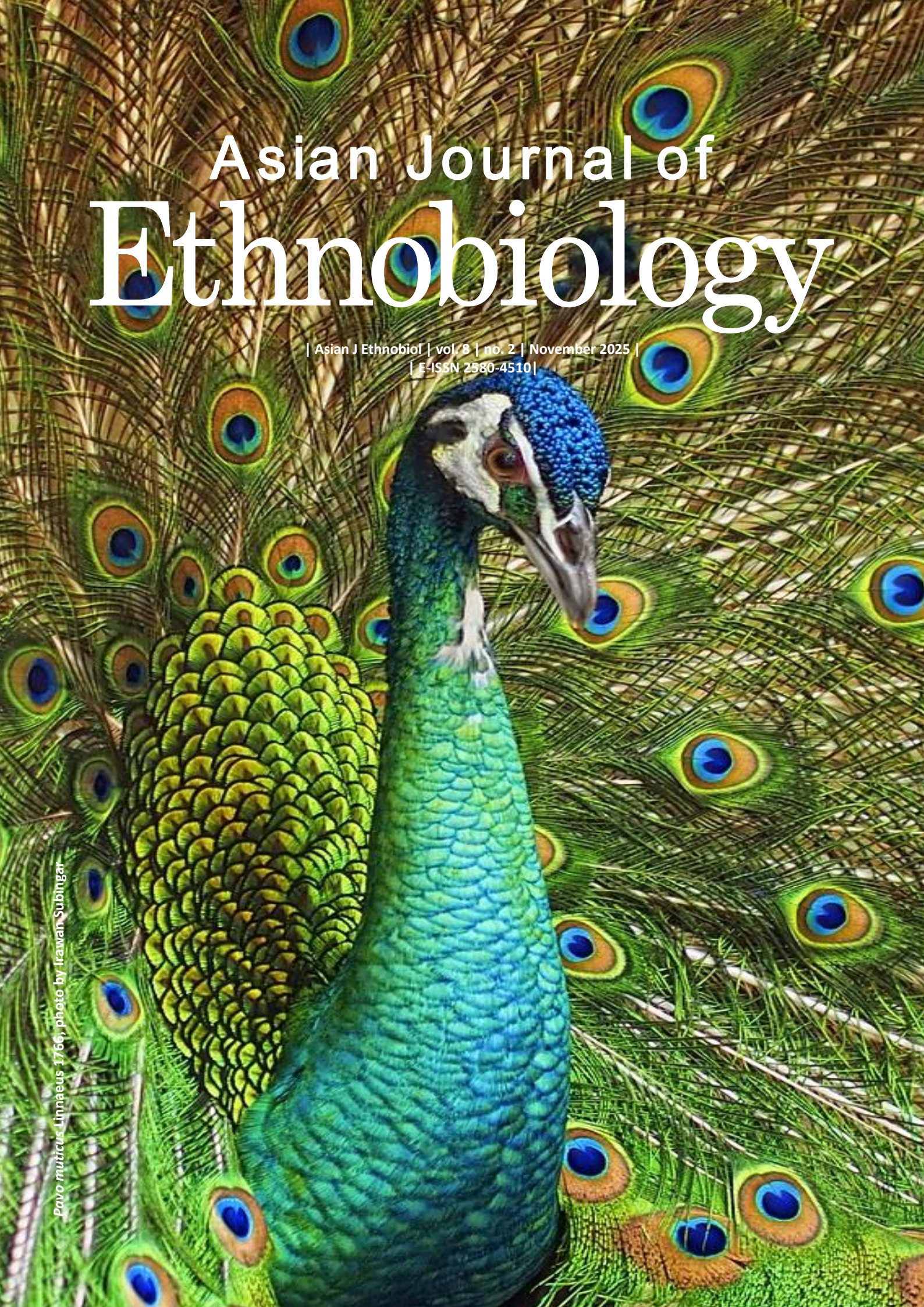

Pavo muticus Linnaeus 1766, photo by Irawan Subingar

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The usage of "et al." in long author lists will also be accepted:

Smith J, Jones M Jr, Houghton L et al. 1999. Future of health insurance. N Engl J Med 965: 325-329. DOI: 10.10007/s002149800025.

Book:

Rai MK, Carpinella C. 2006. Naturally Occurring Bioactive Compounds. Elsevier, Amsterdam.

Chapter in the book:

Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. In: Carson W, Schnitzer S (eds.). Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta*. 50th annual symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.). Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

Information from the internet:

Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. Mol Syst Biol 4: 187. DOI: 10.1038/msb.2008.24. www.molecularsystembiology.com.

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Etnozoological study of green peacock (*Pavo muticus*) on Jātaka Relief at Candi Borobudur, Magelang, Indonesia

SETIYO PRAJOKO♥, IKA SUKMAWATI, FITRIA ALFIYAH HASTUARI
Department of Biology Education, Faculty of Teacher Training and Education, Universitas Tidar. Jl. Kapten Suparman No.39, Magelang 56116, Central Java, Indonesia. Tel./fax.: +62-293-364113, ♥email: setiyoprajoko@untidar.ac.id

Manuscript received: 5 May 2025. Revision accepted: 9 June 2025.

Abstract. *Prajoko S, Sukmawati I, Hastuari FA. 2025. Etnozoological study of green peacock (*Pavo muticus*) on Jātaka Relief at Candi Borobudur, Magelang, Indonesia. Asian J Ethnobiol 8: 141-148.* The green peacock (*Pavo muticus* Linnaeus, 1766) is one of the animals frequently depicted in the Jātaka Reliefs at Borobudur Temple, Magelang District, Central Java, Indonesia; however, scientific research on the ethnozoology aspects remains limited. As a symbol of culture and spirituality in ancient Javanese Society, the presence of this bird in the reliefs has a deep philosophical meaning. This study aims to examine the representation of the green peacock in the Jātaka Reliefs through morphological, morphometric, and cultural symbolism analysis. This study employed a qualitative approach with visual ethnographic methods, including direct observation, photographic documentation, and interviews with cultural and zoological experts. These interviews were crucial in gaining insights into the cultural and religious meanings of the peacock, as well as its role in ancient Javanese Society. Observations of the reliefs were conducted at Borobudur Temple, while comparative morphology was assessed through observations of live green peacocks at the Jagatsatwa Nusantara Bird Park in TMII. The results revealed 9 relief panels depicting green peacocks and 7 panels featuring peacock feather fans, with a dominant representation of males. Morphometric analysis revealed a 99.85% similarity in body proportions, indicating a high level of anatomical accuracy achieved by the ancient sculptors. Additionally, these findings suggest that peacocks were not merely decorative elements but served as symbols of spiritual transformation, purity, and protection within Buddhist teachings.

Keywords: Borobudur Temple, ethnozology, green peafowl, Jātaka Reliefs, morphometry

INTRODUCTION

Indonesia has a rich cultural heritage and biodiversity, one of which is Borobudur Temple, a UNESCO World Heritage Site since 1991 (Ulfahira 2024). As the largest Buddhist monument, Borobudur contains thousands of reliefs representing religious teachings, moral values, and the flora and fauna of the Ancient Mataram period (Munandar 2020). The Jātaka reliefs depict the life of the Buddha in the form of animals as symbols of moral messages, including the green peacock (*Pavo muticus*), which stands out for its beauty and philosophical significance (Gusti 2020).

In Buddhist teachings, the peacock symbolizes spiritual transformation and majesty, believed to be able to neutralize poison as an allegory of enlightenment (Sugianto 2019). Although it dominates Jātaka reliefs, its ethnozoological study remains limited. The peacock serves not merely as an aesthetic element but also as a cultural, mythological, and spiritual symbol in Buddhist narratives and Javanese culture (Raihani 2023). Ethnozoology views fauna as cultural entities rich in meaning, not merely biological creatures.

Human interaction with peacocks during the Ancient Mataram period is reflected in the reliefs and decorative art of Borobudur, indicating a strong social and spiritual role (Susanti et al. 2025). These birds were kept by the elite as symbols of status and were associated with the vāhana of Bodhisattva Mahamayuri, protector from poison (Ānandajoti 2020). Today, their population is threatened by hunting, land conversion, and illegal trade, while their spiritual significance has diminished to a decorative symbol in popular culture (Septianti 2020).

The selection of animals or plants in relief art is influenced by symbolic values, such as courage or wisdom (Santayana and Gouinlock 2015), geographical and ecological conditions that make local species more familiar (Weston 2017), and social-spiritual roles in religious rituals (Simanungkalit et al. 2025). Classical narratives like the Jātaka tales also serve as sources of inspiration (Appleton 2016), while beautiful and striking forms, such as peacocks, enhance visual appeal (Dahlstrom 2025).

Ethnozoological and ethnobiological studies at Borobudur Temple remain limited and fragmented to date. Some existing research includes Febrianto and Idris (2016), who studied the fauna depicted on Borobudur's reliefs from an archaeozoological perspective, identifying species and their connections to the subsistence of the Mataram society. However, the cultural and symbolic dimensions have not been explored in depth. Arfan and Fitri (2024) studied the ethnobotany of the reliefs, revealing the meanings of flora such as bananas and banyan trees, but did not focus on fauna. Mikkelsen (2025) compiled a catalog of fauna from the Jātaka reliefs for local character education, but their approach remained descriptive without morphometric or symbolic analysis. However, this research remains

descriptive and has not analyzed morphometric aspects or further cultural-ecological relationships.

Borobudur Temple, built in the 9th century CE by Mahayana Buddhists during the Syailendra Dynasty, is one of the architectural and religious wonders of Southeast Asia (Nabilla dan Samadi 2024). Its walls are covered with narrative reliefs from the Kamadhatu to the Rupadhatu levels, divided into four main panels: Karmawibhangga, Lalitavistara, Jātaka-Avadāna, and Gandawyuha, totaling 1,460 panels (Setyawan et al. 2017). In Borobudur's culture and spirituality, the peacock symbolizes wisdom, beauty, and virtue, in line with the Jātaka teachings about the Buddha's life before enlightenment. Its presence reflects noble values and the preservation of local culture and ecology.

The Jātaka and Avadāna reliefs at Borobudur Temple are visual narratives rich in moral messages and character building, located on the third level with 500 main panels and 120 additional panels (Defandra 2018). Based on the Jātakamālā tales by Aryasura from the 4th century CE, these reliefs teach values such as kindness, sacrifice, and mutual aid through fables featuring animals as the main characters (Maskur et al. 2020).

Ethnozoological studies of green peacocks in Jātaka reliefs are important for understanding the representation of fauna in the social-spiritual context of ancient societies. This research strengthens cultural and ecological literacy and has the potential to become a source of learning based on local wisdom (Amelia 2022). The symbolism of the peacock also underscores its role as an endangered species and cultural heritage, opening opportunities for conservation based on local values and the preservation of ancestral visual art.

MATERIALS AND METHODS

Study area

The research area is located within the Borobudur Temple complex in Borobudur Village, Borobudur Sub-district, Magelang District, Central Java Province, Indonesia (Figure 1), at coordinates 7°36'28.6"S and 110°12'13.5"E. Built during the Syailendra Dynasty in the 8th century CE, Borobudur Temple is famous for its intricate relief panels that visually convey Buddhist teachings and narratives. This study focuses on the Jātaka narrative panels located on the Kamadhatu and Rupadhatu levels of the temple, which illustrate the previous lives of the Buddha through detailed visual storytelling. Among the fauna depicted, the green peacock (*P. muticus*) emerges as a prominent figure, forming the core of this ethnozoological analysis. This temple was selected as the research site due to its historical depth and symbolic representation of animals reflecting the cosmology, philosophy, and moral values of ancient Javanese society (Yatno 2022).

The research area is located in the Borobudur Temple complex, a Buddhist temple complex in Magelang, Central Java. The main focus of this research is on the balustrades, which consist of stepped corridors surrounding the body of the temple and filled with hundreds of narrative relief panels. One of the most important parts of these reliefs is the Jātaka panels, which depict the stories of the rebirths (reincarnations) of the Bodhisattva before achieving enlightenment as Buddha. It is on these panels that representations of the green peacock (*P. muticus*) are found, which is the main subject of this study. The peacock reliefs are not merely decorative elements but also symbols with deep cultural and religious meanings, reflecting moral values, spirituality, and the relationship between humans and nature in the context of Buddhist teachings. Therefore, observing these reliefs is crucial for uncovering how fauna, particularly the green peacock, is represented and interpreted within the visual and narrative structure of Borobudur Temple.

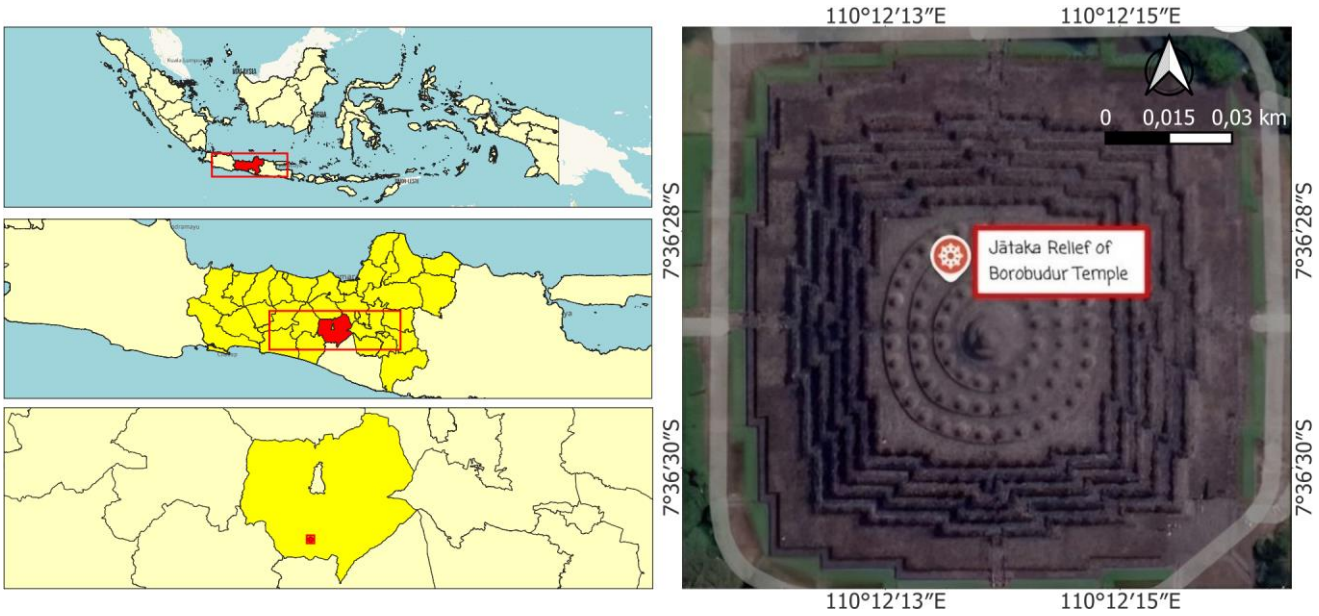


Figure 1. Map of the research area in the relief of the Jātaka Temple at Borobudur, Magelang, Central Java, Indonesia

Instruments

The instruments used in this exploratory ethnozoological research were observation guidelines and identification sheets for green peacocks (*P. muticus*) on reliefs. Each observation session uses guidelines and structured observation sheets. The relief observation instruments emphasized narrative, symbolic, and visual anatomical aspects of peacocks. Meanwhile, the observation instruments at the zoo focused on direct observation of the behavior, physical characteristics, and habitat conditions of the peacock. The observation instrument grids for reliefs and native peacocks can be seen in Tables 1 and 2.

Data collection

An ethnographic research design was used to examine and describe the object of study, namely the use of fauna in the Jātaka Reliefs at Borobudur Temple (Table 3). In this design, the study is based on written and oral findings from the community group being studied. The ethnographic research data instruments used are observation sheets, interview sheets, and documentation. The flow of ethnographic research can be seen in Figure 2.

This research design uses a qualitative ethnographic approach, which aims to understand the symbolic meaning of the peacock *(P. muticus)* in the Jātaka Reliefs at Borobudur Temple through the lens of culture, spirituality, and human-animal relations in the context of ancient Javanese Society. The ethnographic approach was chosen because it is capable of exploring in depth the relationship between cultural artifacts (reliefs), belief systems, and local values internalized in animal representations (Semuel et al. 2022).

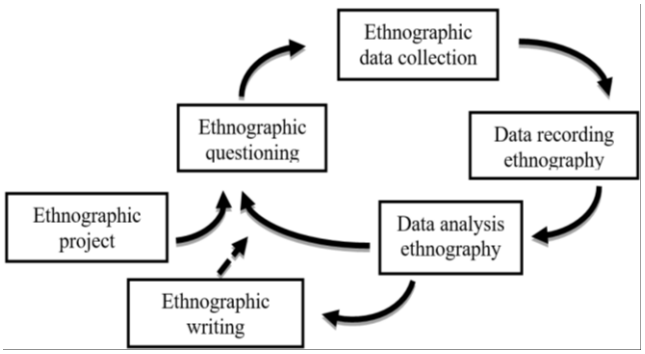


Figure 2. An ethnographic research scheme (Source: Fadila dan Yulifar 2023)

Table 1. Observation instrument grid for identifying peacocks on the Jātaka Reliefs of Borobudur Temple

Aspects observed	Criteria
Panel data relief	Panel number and location, position in row and temple plane
Physical description of peacock	Body shape, body position, visible body parts, tail and crest characteristics
Gender identification	Based on body proportions and secondary sexual characteristics such as tail length
Narrative context	Scenes in reliefs involving peacocks, such as interactions with human figures or other animals
Symbolic meaning	Symbolic interpretations of the peacock in a Buddhist context, such as fertility, protection, and wisdom
Additional information	Artistic information, relief conditions, or field companion interpretation

Table 2. Lattice of live peacock observation instrument at Jagatsatwa Nusantara Bird Park TMII

Aspects observed	Criteria
Peacock species	Taxonomic identification (e.g., *Pavo cristatus*, *Pavo muticus* Linnaeus, 1766)
Physical traits	Coat color, body size, tail length, crest shape, male and female differences
Behavior	Feeding activity, vocalizations, territory defense, and mating dance
Environmental conditions	Habitat types, vegetation, water sources, and interactions with the environment
Gender differences	Direct observation of sexual dimorphism
Ecological role	The function of peacocks in ecosystems, such as seed dispersers or environmental indicators
Additional information	Conservation status, human interaction, symbolic or cultural value

Table 3. Methodology for exploring peacocks in the Jātaka Reliefs of Borobudur Temple

Data type	Data collection methods
Exploratory descriptive research	This study was conducted to explore and identify Jātaka relief panels depicting animals at Borobudur Temple
Material analysis	Analyze relief panels featuring animals through field observations using observation sheets and photo documentation
Animal data analysis	The data obtained were further analyzed, including morphological character analysis, taxonomic analysis for species identification, story analysis in the context of Jātaka, and morphometric analysis of relief images
Data validation	The data from animal identification and analysis were validated using validation sheets with relevant experts to ensure the accuracy of interpretation
Profile preparation	Based on the data and validation results, a profile of the peacock in the Jātaka relief was compiled, covering biological, cultural, and artistic aspects

This study focuses on Jātaka panels depicting peacocks using different approaches. Panels 45, 79, 87, 95, 96, 136, 137, 138, and 317 are the main subjects of visual observation and field documentation conducted at the Borobudur Temple site. The objective is to understand the details of the peacock ornaments, carving styles, and narrative context of these panels within the Jātaka story. This visual data is then contextualized with the narrative of the Jātaka story, Buddhist mythology, and the conservation and virtue values represented by the peacock in tradition.

Within an interdisciplinary ethnographic framework, this study not only describes visual forms but also interprets the peacock's symbolism as a cultural entity representing virtue, wisdom, and the sacred relationship between humans and nature. We also use supporting literature from Buddhist texts and iconographic studies to reinforce the cultural interpretation of the research object (Fakhruddin et al. 2019).

Data analysis

This study uses a qualitative design with an ethnographic approach, which aims to reveal the symbolic meanings and cultural values contained in the representation of peacocks (*P. muticus*) in the Jātaka Reliefs at Borobudur Temple. The ethnographic approach was chosen because it allows us to understand the perspectives and cultural wisdom of past societies through visual artifacts rich in meaning, in this case the reliefs depicting peacocks as symbols of wisdom, beauty, and protection in Buddhist teachings (Trisnayanti 2015).

This study focuses on Jātaka Relief panels depicting peacocks metaphorically and symbolically, such as panels numbered 45, 79, 87, 95, 96, 136, 137, 138, and 317, as well as panels depicting peacock feather fans, such as panels 170, 200, 206, 276, 292, 367, and 369. Observations were conducted directly at the Borobudur Temple site by documenting the visual forms, narrative contexts, and artistic styles of the sculptures.

In the context of visual ethnography, this design not only explores the aspects of form and composition of the relief but also links the symbolism of fauna with the moral values, spirituality, and ecological relationships of the ancient Javanese Society. This study combines field observations, narrative interpretations, and cultural literature reviews to form a holistic and in-depth understanding of peacock symbolism in the context of Jātaka Reliefs (Sasongko and Susanti 2021).

RESULTS AND DISCUSSION

Visual identification results

Nine relief panels depicting green peacocks (*P. muticus*) and seven panels depicting peacock feather fans were found. These reliefs are scattered on the outer side of the Jātaka cornice, and their distribution is shown in Table 4.

Each relief panel depicting peacocks at Borobudur Temple implies different behaviors and symbolic meanings through the birds' body positions and narrative contexts. In panel 79, peacocks standing upright near a rain scene symbolize vigilance and their spiritual role as bringers of fertility and renewal. On panel 317, the peacocks perched on a tree show an observing behavior from above, reflecting spiritual protection and the connection between the earthly and divine realms. In panel 96, the peacocks above, with elements such as fans, show vigilance and surveillance from the spiritual realm as if they are wise observers of actions on earth; this role adds an interesting layer to their symbolism. Panel 45 shows a peacock sitting calmly on the temple wall, signifying appreciation for beauty and noble values in spirituality.

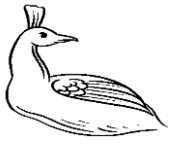
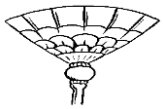
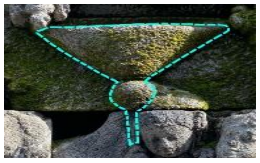
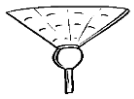
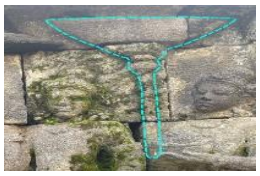
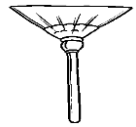
Panel 136 shows a female peacock perched naturally on a tree, symbolizing harmony and peace in the balance of the ecosystem. In panel 137, a male peacock is at the center of interactions between fauna, highlighting their role as a focal point and spiritual symbol in the dynamics of the forest. Meanwhile, panel 138 shows a peacock among the trees, expressing unity between fauna and the environment. Panel 87 depicts a peacock perched gracefully on a tree branch, reflecting freedom, observation, and spirituality in the transitional space of the forest.

Panel 95 features a peacock observing from atop a tree, reinforcing the symbol of gentle dominance and balance amidst the diversity of wildlife. Panels depicting peacock feather fans, such as Panels 367, 369, 170, 200, 206, 276, and 292, depict symbolic attributes resembling the peacock's position when spreading its tail, signifying grandeur, spiritual protection, and wisdom upheld in Buddhist teachings, as well as a balanced ecosystem integrated into the temple landscape.

The royal fan sketch was chosen as the focus of analysis because it has a deep symbolic meaning in the cultural and religious context depicted in the reliefs of Borobudur Temple. The royal fan is an attribute that symbolizes status, power, and protection and is often associated with the greatness and glory embodied by important figures, including the peacock symbol (Brown 2025). The distinctive and easily recognizable shape of the fan also facilitates iconographic analysis, providing a clear visual focus for examining the symbolic relationship between the peacock motif and royal attributes (Santosa and Noorwatha 2025). Therefore, sketches of royal fans were prioritized over other parts of the relief.

The higher frequency of male peacocks in reliefs compared to female peacocks can be explained from several perspectives. Biologically, male peacocks do have more beautiful and striking feathers than females, making them more attractive to be depicted as symbols of beauty and grandeur in relief art (Godfrey 2025). From a cultural and social perspective, in Javanese tradition and Buddhism, male figures are often associated with symbols of dominance, strength, and high status. This explains why male peacocks are more often chosen as representations (Deming 2025). Additionally, in religious and social contexts, the depiction of male peacocks with their magnificent tail feathers serves as a metaphor for purity, spiritual rebirth, and royal protection (Dahlstrom 2025). Therefore, this difference in frequency is more closely related to the symbolic and aesthetic values associated with male peacocks in cultural and religious traditions, rather than simply because there are more male peacocks than female peacocks in nature (Mackay 2025).

Table 4. The presence of peacocks and peacock feathers in the Jātaka Reliefs at Borobudur Temple

Gender of aves	Panel no.	Relief Image	Sketch
Male	79		
Female	317		
Male	96		
Male	45		
Female	136		
Male	137		
Female	138		
Male	87		
Male	95		
Royal fan	367		
Royal fan	369		
Royal fan	170		
Royal fan	200		
Royal fan	206		
Royal fan	276		
Royal fan	292		

In the entire relief panels of Borobudur Temple featuring peacocks or peacock feather fan motifs, the visual position of the bird or symbol is always placed within an interconnected ecological and narrative context. Peacocks never appear as isolated elements but are present alongside important elements such as trees, water, other animals, humans, and spiritual figures. In Relief Panel 45, the peacock is depicted sitting on the temple wall on the left side of the panel alongside a worshipper paying homage. This signifies the peacock as a guardian of the sacred space and a bridge between the human world and spiritual architecture. In relief panel 79, the peacock is placed at the bottom right, near a scene of refreshing rain falling on the ground after the sacrifice of a rabbit. This position reinforces the peacock's meaning as a symbol of fertility, renewal, and regeneration, closely related to the element of water.

Furthermore, panel relief 87 depicts a peacock perched on a large tree in a forest landscape, close to the hand of a peeping monkey. This scene reflects the transition between the wild forest and the outside world, with the peacock as the guardian of ecological and spiritual harmony. In relief panel 95, the peacock is placed at the top of the panel, among the trees, alongside various fauna such as elephants, deer, buffalo, and wild boars. This underscores the peacock's role as part of a harmonious ecological community within the tropical forest. A similar position is found in relief

panel 96, where the peacock is depicted above, flanked by fan-shaped elements connected to the bird's head, with a river in the background. In this context, the peacock represents a higher spiritual consciousness, acting as an observer of good deeds from above.

In relief panel 136, a peacock perches on a tree above a scene of the Bodhisattva facing a lioness in her den, reinforcing the peacock's role as guardian of the balance between spiritual and animal forces. In relief panel 137, a monkey is seen holding a peacock's tail in the center of the panel while a wolf stands on the other side. This interaction reveals the dynamics between wild forest creatures and birds with transcendental meaning. Moving on to relief panel 138, although part of the relief is damaged, the peacock is still visible among the trees, close to the fish in the river, emphasizing its role in the web of life in the terrestrial and aquatic ecosystems.

Panel relief 317 also depicts a peacock perched on a tree above five women who appear to be discussing something. The peacock in this position conveys a sense of spiritual supervision from above, symbolizing rebirth and contemplation. Meanwhile, in a series of panels featuring peacock feather fan motifs, such as panels 367, 369, 170, 200, 206, 276, and 292, these fans are usually positioned above or near the main figures, such as Bodhisattvas, kings, or figures engaged in discussion or receiving offerings. These fans are often positioned above the head or in the center of the composition as symbols of spiritual protection, majesty, or wisdom. For example, in panels 367 and 369, fans are held by figures in social and spiritual contexts, symbolizing status and honor. In panels 170 and 206, the position of the fan above the figure emphasizes the meaning of spiritual protection and the attainment of wisdom.

The results of the analysis of the table show that green peacocks, especially males, have a higher frequency of appearance than female peacocks on the Jātaka Relief panels at Borobudur Temple. In addition, the representation of peacock feathers, which are characteristic of male peacocks, is scattered across seven different panels.

Morphometric analysis of peacocks

The proportions of the peacock's body part in the Jātaka Relief compared to their actual size show a significant difference in scale. The results of the size comparison are shown in Table 5. After determining the size comparison of peacocks, the level of similarity that has accumulated can be determined. The results of the analysis of the similarity level of the body proportions of peacocks in the Jātaka Relief with their actual size is 99.85%. Similar results can be seen in Table 6.

The percentage of similarity was calculated based on the difference between the proportion values (ratio of body part length to total body length) of the relief and the actual specimen, which included a comparison of the body length ratio in the relief and the actual length of the green peacock specimen. The formula used to calculate the percentage of similarity is as follows (Dasore et al. 2022):

Similarity presentation = 100% - (Difference between relief and real proportion)

This formula is important to show the extent to which the visualization of peacocks in relief can represent anatomically accurate proportions. An average similarity value of 99.85% indicates that the representation of peacocks in relief is quite accurate when compared to their original form, even though they are created in an artistic and symbolic context.

Discussion

The green peacock (*P. muticus*) in the Jātaka Reliefs at Borobudur Temple, an important subject in the fields of art history and archaeology, is consistently depicted with a high degree of morphological accuracy. Observations show that the morphological details of this bird are depicted in great detail, both in male and female peacocks. The male peacock is characterized by an upright posture, a long tail that is not always spread out, and a fan-shaped crest on its head (Susanti et al. 2025). This level of accuracy indicates that the sculptors of that time did not rely solely on artistic imagination but had a deep understanding of the physical characteristics of the animals they depicted (Wulandari 2022). Despite the limitations of stone as a medium, the body shape, perching position, and proportions of the birds are depicted with great detail (Febrianto and Idris 2016).

Table 6. Percentage of similarity in the proportions of peacock body parts in Jātaka Reliefs and actual size, with reference to Ravindran (2025)

Body parts	Formula	Similarity percentage
Head	(100% - 0.13%)	99.87%
Beak	(100% - 0.2%)	99.8%
Wings	(100% - 0.25%)	99.75%
Cervical vertebrae	(100% - 0.05%)	99.95%
Tarsus	(100% - 0.1%)	99.9%
Average		99.85%

Table 5. Comparison of the proportions of peacock body parts in Jātaka Reliefs with actual sizes, with reference to Arjun et al. (2025)

Body parts	Long		Body measurement section	Total length		Ratio	
	Relief	Real		Relief	Real	Relief	Real
Head	4.4 cm	4 cm	Headbill (beak-head)	6.6 cm	8.5 cm	1 : 1.5	1 : 2.1
Beak	2.2 cm	4.5 cm	Headbill (beak-head)	6.6 cm	8.5 cm	1 : 3	1 : 1.8
Wings	11.8 cm	43.5 cm	Head-body	17.5 cm	104 cm	1 : 1.5	1 : 2.3
Cervical vertebrae	7.8 cm	41 cm	Total body-tail length (x) head	17.5 cm	10 cm	1 : 2.2	1 : 2.5
Tarsus	5.2 cm	18.5 cm	Total toe-foot length	10.5 cm	30 cm	1 : 2.01	1 : 1.6

The distribution of peacocks in the reliefs also shows a non-random pattern. Out of the nine identified panels, six depict male peacocks, while only three feature female peacocks. Additionally, the fan-shaped tail feathers of male peacocks appear in seven different panels. This suggests that male peacocks, which are more visually striking, were more frequently chosen as the main subject in the visual narrative. This representation not only emphasizes aesthetic value but also reinforces symbolic meanings such as grandeur, beauty, and spiritual value in the context of Buddhist teachings (Handayaningsih 2018). This visual dominance indicates that the depiction of fauna in reliefs was not done arbitrarily but was rooted in a strong narrative and philosophical foundation (Davidson 2018).

Quantitatively, morphometric analysis of the five parts of the peacock depicted in the relief, namely, the head, beak, wings, neck bones (vertebrae servikalis), and tarsus, shows a very high degree of similarity to the proportions of living peacocks. The average similarity score reached 99.85%, with the neck bones showing the highest level of similarity (99.95%) and the wings the lowest (99.75%). These findings indicate that ancient artists not only considered visual and aesthetic aspects but also paid attention to biological accuracy in representing animals (Roy et al. 2025).

Such precision indicates the integration of local zoological knowledge with traditional artistic practices. Minimal adjustments to proportions were likely made for artistic composition and the conveyance of visual symbols within the limitations of stone as a medium (Wahyudi et al. 2025). The discovery of seven panels depicting peacock tail fans also indicates the symbolic importance of this body part. Not all peacocks are depicted in their entirety, but the separately depicted tail feathers highlight their significance as symbols of majesty, protection, or even rebirth, aligning with Buddhist values. These visual elements serve as nonverbal narrative markers that reinforce the moral messages in the Jātaka stories carved on the reliefs (Nagamine 2025).

In the context of modern society, the green peacock also plays an important ecological and cultural role. As a species currently classified as endangered by the IUCN, the green peacock serves as an indicator of the health of tropical forest and savanna ecosystems, its natural habitat (Patil and Vijay 2024). Its presence reflects relatively intact environmental conditions, as this bird is highly sensitive to habitat disturbance and illegal hunting. Beyond its ecological functions, the peacock also holds contemporary symbolic value as a representation of conservation, natural beauty, and cultural heritage (Dhiman 2024). In various regions of Southeast Asia, including Indonesia, peacocks are often used as icons in environmental conservation campaigns and are an important subject in culture-based ecological education (Ciptandi et al. 2025). Thus, the visual heritage of the Jātaka Reliefs not only reflects past understanding but is also relevant in promoting public awareness of the importance of conserving this species in the present.

This study concludes that the green peacocks depicted in the Jātaka Reliefs at Borobudur Temple are not merely decorative elements, but have complex representational functions. These reliefs not only depict the morphology of the birds with precision, but also predominantly feature male subjects to reinforce aesthetic and symbolic values. The strategic placement of peacocks and their body parts in various panels indicates that this fauna plays an important role in conveying the moral, spiritual, and philosophical messages that form the core of the Jātaka narrative. In addition, this visual heritage can serve as a reminder and reinforcement of ecological conservation values amid the challenges of biodiversity sustainability today.

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Ethnobotany of local banana (*Musa* spp.) in Sentani community and its proximate analysis in Jayapura District, Papua, Indonesia

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Abstract. *Zebua LI, Purnamasari V, Suharno. 2025. Ethnobotany of local banana (*Musa *spp.) in Sentani community and its proximate analysis in Jayapura District, Papua, Indonesia. Asian J Ethnobiol 8: 149-157.* The proliferation of banana cultivation spans the entirety of Indonesia, with each distinct area showcasing a diverse array of indigenous variants. The distribution of bananas in Papua is quite extensive, and has significance for local communities who still depend on local foodstuffs. Therefore, this study was conducted to determine the use of local banana varieties based on the knowledge of the Sentani people. The morphological attributes and nutritive composition inherent to native Papuan bananas were analyzed through physical characteristics and proximate analysis (moisture content, ash content, crude fiber, fat content, protein content, and total carbohydrates). Furthermore, descriptive, qualitative, and quantitative methods were used, and the locations were based on purposive sampling in Ayapo, Yahim, Harapan, Doyo, and Netar Villages. The results showed that the Sentani people recognized t10 local banana varieties, namely *Anakhola*, *Aomang*, *Buwakhu*, *Emfofo*, *Hoyombi*, *Keija*, *Molonsi*, *Olowambu*, *Remuhu*, and *Wabulu*. Bananas, beyond their nutritional value, played a significant role in traditional ceremonies, serving as food ingredients, delivery materials during traditional engagement parties and weddings, and gifts for grieving families. The results of the proximate analysis indicated a significant difference ($p < 0.05$) in protein content between the banana varieties. However, there were no significant differences in fat, moisture, ash content, or carbohydrate content ($p < 0.05$). Protein levels in a row from the highest were found in *Buwakhu, Emfofo*, *Hoyombi*, *Keija*, and *Remuhu*.

Keywords: Ethnobotany, local bananas, proximate, Sentani, Sentani community

INTRODUCTION

Bananas are multi-purpose plants, starting from roots, stems (humps), pseudostems (midribs), leaves, flowers, and fruit used for various purposes (Kumari et al. 2023; Suharno et al. 2025). Banana is a tropical plant that grows throughout the year in an environment with an average annual rainfall of 650-750 mm, temperatures ranging from 15 to 35°C, and relative humidity levels between 75-85%. Of the total banana crop in the world, most cultivation is done in India (31.5%), followed by China (11.5%), Indonesia (8.2%), Brazil (6.6%), Ecuador (6.2%), Philippines (6%), Guatemala (4.4%), Angola (4.1%), Tanzania (3.4%), Costa Rica (2.5%), and other tropical countries (15.6%) (Badanayak et al. 2023). In Indonesia, banana is planted by the community as garden plants or plantations on a small scale. The fruits (*Musa* spp.) contain a high source of carbohydrates, minerals, vitamin B6, and vitamin C. The nutritional content contained in ripe bananas includes potassium and vitamin A. Furthermore, carbohydrates are also used to store muscle glycogen reserves (Wulandari et al. 2018; Hapsari et al. 2024).

Bananas are one of the most important fruit commodities in Papua and are identified as *Musa* ×*paradisiaca* L., family Musaceae, and Order Zingiberales. A total of 12 species have been recorded in Indonesia from the 66 species of bananas in the world (Widjaja et al. 2014; Zebua et al. 2023). The plants are suitable for growing in tropical areas and can bear fruit in the year. Bananas have many varieties, including *Ambon*, *Ataka*, jackfruit, *kepok*, milk, plantains, rhinoceros, and sparrow bananas (Poerba et al. 2016; Riandini and Astuti 2020; Riandini et al. 2021).

Ethnobotany studies on bananas have been carried out with different perspectives and objectives. Kasrina and Zulaikha (2013) investigated on diversity and ethnobotany of bananas (*Musa* spp.) in the community of Sri Kuncoro Village, Pondok Kelapa Sub-district, Central Bengkulu District, Indonesia. Furthermore, Hapsari and Lestari (2016) examined an ethnobotanical study of banana diversity in six areas in Java. One of the local wise of agricultural cultivation, specifically food crops, is the development of local knowledge in recognizing and identifying these varieties of plants (Zebua and Waluyo 2016; Amelia et al. 2018). Identification has been carried out by humans to distinguish one plant from another based on certain characteristics (Purnamasari et al. 2020; Riandini and Aastuti 2020; Riandini et al. 2021). Banana is a fruit plant that has high diversity with the ability to grow and adapt to an environment of high rainfall and a variety of habitat types (Sunandar and Kurniasih 2019; Hapsari et al. 2024; Suharno et al. 2025).

The ability of the plants to interact with genetic factors results in an abundance of banana species, specifically in terms of providing food sources (Zulfahmi et al. 2024; Suharno et al. 2025). In some areas, bananas are a source of local food diversification, processed into flour (Zulfahmi et al. 2024). The Sentani community inhabits the entire area of Lake Sentani, and to meet daily needs, the people work

their fields by planting bananas, sweet potatoes, and vegetables (Widjaja et al. 2014). In this community, bananas have important cultural values, and besides being consumed and sold in the market, the plants are often used as payment for dowry. Therefore, several varieties are planted, namely *Aomang*, *Ebulu*, *Habili*, *Rotrowi* bananas, and *Yokholo* (Ondikeleuw et al. 2016).

The exploration of the potential of bananas as viable food sources remains unexplored. This study seeks to identify the indigenous banana cultivars and explore their uses based on the local wisdom of the Sentani community. This research is significant in elucidating the role of local bananas and their potential utilization as a local food source.

MATERIALS AND METHODS

Study area

This study was conducted in June-November 2023 in five observation villages around Lake Sentani, namely: Ayapo, Harapan, Netar (Sentani Timur Sub-District), Doyo (Waibu Sub-District), and Yahim (Sentani Sub-District) (02º30'639"-02º39'194"S 140º27'916"-140º35'237"E) (Figure 1). The locations of the villages were selected based on the presence of local banana varieties planted in the Sentani community gardens. The Sentani people mostly live around Lake Sentani and the buffer zone of the Cycloop Mountains Nature Reserve. Most of this area is open land and secondary forest. According to BPS-Statistics Indonesia of Jayapura (2025), this location is at an altitude of 80-100 masl, average temperature of 26°C, and air humidity of 77%, with rainfall of 2,868 mm/year.

Data collection

Ethnobotanical survey

The designation of informants was conducted using a purposive sampling technique (Martin 2004; Nugraha et al. 2024). Informants were natives of Sentani, with an age range of 25-78, and individuals with knowledge about local banana varieties and their forms. Based on these criteria, 55 informants were obtained, consisting of banana farmers, sellers, and others from the general public around Lake Sentani.

The ethnobotanical survey was conducted through the interview method to obtain data on *Musa* spp. and the use of local bananas (Iskandar et al. 2018). The open-ended interview technique was used based on the interview guide prepared previously. The interview process was carried out at the house of the informant and in the field to show the specimen with the use of local bananas. The questions asked of the respondents were broadly related to community knowledge of local bananas, their use, their role in traditional events, their cultivation, processing, and marketing.

Collection of bananas

The acquisition of banana specimens and pertinent sample data was executed through a comprehensive approach involving both interview and exploratory methodologies (Iskandar et al. 2018). Specifically, this included engaging in structured interviews with a cohort of five distinguished key informants, possessing intricate insights into Sentani banana varieties. Data collection was supplemented through tracing and exploration of the study site's terrain, denoting the precinct of banana cultivation. This locale, intricately situated in the vicinity of domiciles and communal gardens encircling Lake Sentani, was examined to glean pertinent information. Specimens were taken from flowering and fruiting banana plants, and each individual was collected to make 3 to 5 duplicate specimens. The herbarium specimens were kept at the Laboratory of Biological Plant Systematics, Universitas Cenderawasih, Jayapura, Papua.

The banana specimens collected had complete morphological characteristics, including vegetative (pseudostems, leaves, and tillers) and reproductive parts (flowers, fruits, seeds). Morphological identification was carried out using the descriptor guidelines from the International Plant Genetic Resources Institute (IPGRI 1996). Identification included pseudostem, petiole, leaf, flower, and fruit characters.

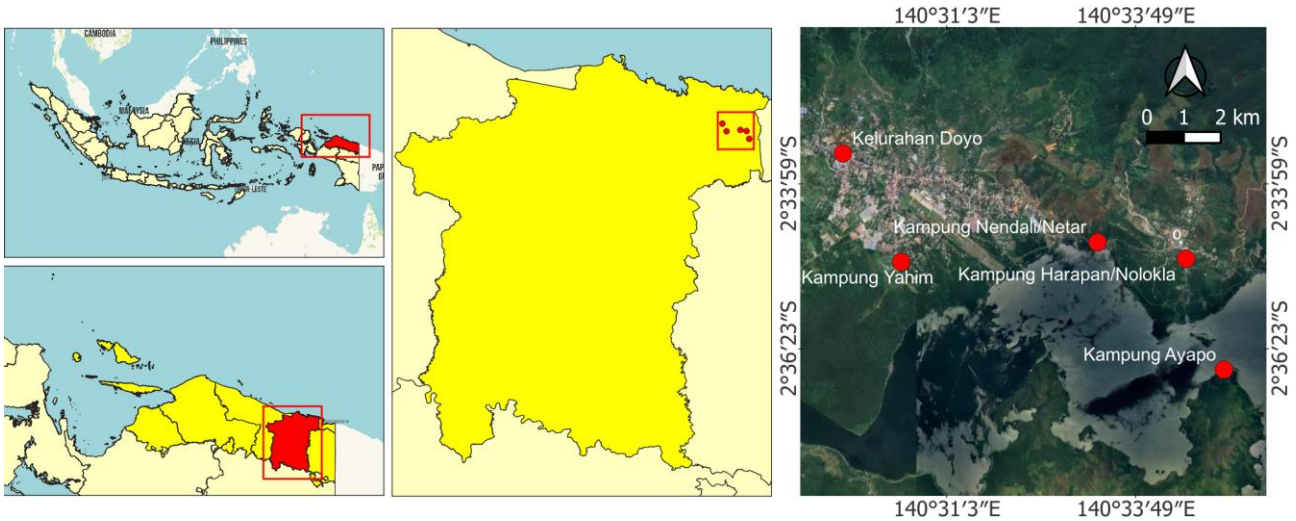

Figure 1. Location of local banana samplings in Sentani Sub-district, Jayapura District, Papua, Indonesia: Ayapo, Harapan, Netar, Yahim, Doyo

Proximate

An in-depth analysis of the chemical content of local bananas was conducted, including the assessment of nutritional components through the application of proximate analysis methodology (Khadijah 2019; Sihmawati and Rosida 2020). The aim was to quantitatively determine the principal constituents of a food ingredient based on their chemical constitution and functional attributes. The key components included water, ash, crude protein, crude fat, and non-nitrogenous mass categorized as carbohydrates.

Proximate test of ash, crude fiber, lipid, and protein was carried out as described by the official methods of the Association of Official Analytical Chemists (AOAC 2016). The analysis was conducted for five varieties of local bananas, Sentani, with three replicates. Moisture content was determined using a hot air oven and expressed as % (percent) (AOAC International 2016). Kjeldhal methods were used to determine the crude protein content (N X 6.25) (AOAC International 2016). Furthermore, total fat content was determined using the Soxhlet method and expressed as % fat on a wet basis. A known weight of the sample was extracted in petroleum ether (boiling point 40-60°C) using a Soxhlet (AOAC International 2016). Alkalinity and the gravimetric method were also used to determine the ash content in the samples and expressed as a % a wet basis (AOAC International 2016). The crude fiber was determined using the digestion method, and a known weight of the fat-free sample was digested with refluxing in 1.25% sulfuric acid and 1.25% sodium hydroxide (AOAC International 2016). The difference method was used for the determination of total carbohydrate content in the samples. The total percentages of ash, crude fiber, crude protein, fat, and moisture were subtracted from 100%.

Data analysis

Qualitative and quantitative analyses were used in this study. The data from the interviews were then recapitulated and transcribed into the qualitative analysis. Quantitative data obtained from interviews were presented in the form of a description of morphological analysis. The morphological analysis of banana varieties was tabulated in a table containing information on the local names, stems, leaves, and fruit morphology (Martin 2004; Iskandar et al. 2018). The results were expressed as mean ± standard deviation, and the significant differences between means were determined by one-way ANOVA with Tukey grouping at a 95% confidence level using SPSS version 15.0 (Landau and Everitt 2004).

RESULTS AND DISCUSSION

Community knowledge of local bananas

The results indicate that the Sentani community living around Lake Sentani is generally familiar with local banana varieties. This recognition is rooted in traditional knowledge, as reflected in the variety of local names for bananas. A majority of respondents (78.18%) are aware of local bananas, while 14.55% are not familiar with them. Furthermore, many understand the cultural significance of bananas: 90.91% acknowledge their role in customary practices, 81.82% recognize their use as part of dowries in marriage ceremonies, and 100% note their presence in mourning rituals and other traditional events. Additionally, 96.36% understand that bananas have economic value and are sold in traditional markets. However, awareness of banana species diversity is lower, only 50.91% of the community can distinguish different species, while 36.36% are unaware of this diversity. Interviews also reveal that 67.27% of community members cultivate local bananas, but others remain unsure or do not engage in cultivation (Table 1). This suggests that while awareness of bananas' cultural and economic roles is high, understanding and practices related to species diversity and cultivation remain limited.

Interview results suggest that knowledge of local banana diversity is mostly retained by traditional elders and older individuals (over 60 years old). At the same time, younger generations tend to have a more limited understanding. According to Suharno et al. (2016) and Zebua et al. (2020), communities in Papua remain highly dependent on natural resources in their environment. The transmission of knowledge to younger generations typically occurs through experiential learning, children are involved in daily activities such as hunting, gathering, and farming alongside their parents. This natural learning process also includes the transfer of cultivation practices. Maintaining this intergenerational transfer of knowledge is essential to ensure that children and their descendants continue to understand and preserve traditional knowledge sustainably.

Table 1. Community knowledge of local bananas in Sentani, Jayapura, Papua

Knowledge of communities on bananas	Community responses (%)		
	Understand	Hesitate	Not understand
People recognize Sentani's local banana fruit	78.18	7.27	14.55
People can distinguish species diversity based on local knowledge	50.91	12.73	36.36
People understand the importance of bananas in the customary system	90.91	0.00	9.09
The community knows the use of bananas in traditional ceremonies, such as for a complementary dowry	81.82	5.45	12.73
Knowing the use of bananas in other cultures, such as death ceremonies and other activities	100	0.00	0.00
Do they cultivate local bananas	67.27	14.54	18.18
Does the community also sell local bananas to the general public (in the market)?	96.36	1.82	1.82

The Sentani community considers local banana cultivars to hold great importance within their customary and cultural systems. In marriage traditions, certain banana cultivars, such as *Aomang* and *Keija*, are highly valued. The groom's family customarily offers these varieties to the bride's family during engagement ceremonies. In the event of a death in the community, family members and relatives bring offerings to the grieving family, and bananas are among the primary items shared. All available banana cultivars are given as a gesture of solidarity, aiming to ease the burden on the bereaved family (Figure 2) and ensure they have sufficient food during the mourning period (Figure 3).

However, the continued existence of these local banana varieties is at risk if cultivation practices are not sustained. According to Salas-Pascual and Cáceres-Lorenzo (2022), the spread of banana plants is largely driven by human intervention, especially for commercially popular varieties. This trend may threaten the survival of local cultivars, which often receive less attention and are at risk of being neglected or replaced.

In Papua, bananas remain an important source of food, especially fruit, and are also used in traditional ceremonies (Zebua et al. 2023; Suharno et al. 2025). Despite their cultural and dietary relevance, banana utilization is still relatively limited. Therefore, innovation is needed to develop bananas as a source of functional food and to explore their potential in processed products. In addition, further information on their nutritional content and physicochemical properties is essential to harness their potential fully.

Diversity of Sentani local bananas

Based on the results in five villages and interviews with key informants, it was discovered that the Sentani community utilizes 10 distinct local banana varieties. The community recognizes these bananas, cultivated over a long period, and recognizes local varieties based on fruit morphology (Figure 4; Table 2). The Sentani community's classification of local bananas is based on morphological characteristics, including leaf texture, fruit tip shape, fruit taste, number of combs in one bunch, and how to use the fruit. The plants had important cultural values beyond their consumption and sale at the market. Local bananas are often used as a means of paying dowry, a tradition that underscores the community's rich cultural heritage and traditions. Hence, the community always plants several cultivars in their gardens.

Table 2. The morphological diversity of bananas based on the local knowledge of the Sentani community

Local name	Morphological characters				
	Leaf texture	Fruit tip shape	Fruit taste	Av. no, of bananas in a bunch	How to process fruit
Anakhola	Thick	Acuminate	Sweetness	3	Boiled
Aomang	Thick	Rounded	Soursweet	8	Boiled
Buwakhu	Intermediate	Acuminate	Sour	4	Eaten immediately
Emfofo	Thin	Rounded	Sour	6	Boiled
Hoyombi	Thick	Rounded	Soursweet	4	Boiled
Keija	Intermediate	Acuminate	Sweetness	7	Boiled
Molonsi	Thin	Acuminate	Bittersweet	6	Boiled
Olowambu	Thick	Rounded	Sweetness	7	Eaten immediately
Remuhu	Thin	Acuminate	Sweetness	2	Boiled
Wabulu	Thick	Acuminate	Sour	6	Boiled

Figure 2. Various varieties of local Sentani bananas at the mourning event in Yoboi Village, Sentani

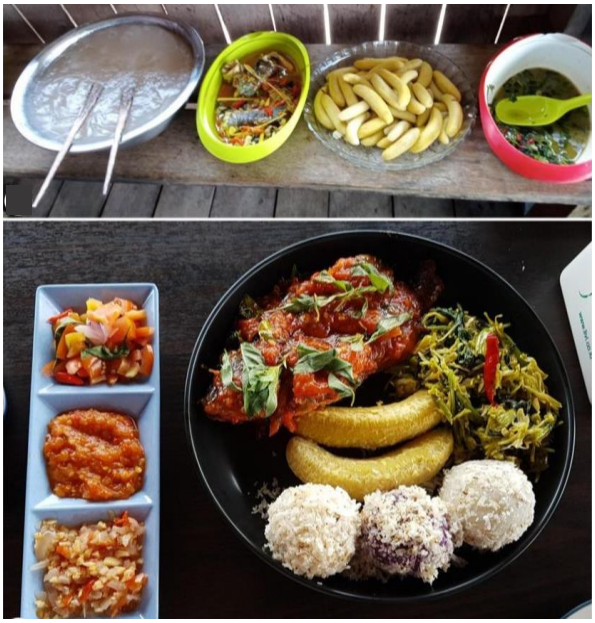

Figure 3. Keija banana, traditionally used as the main food ingredient in traditional events of the Sentani community, is now starting to be used as a food ingredient for the general public with diabetes in one of the Lake Sentani restaurants

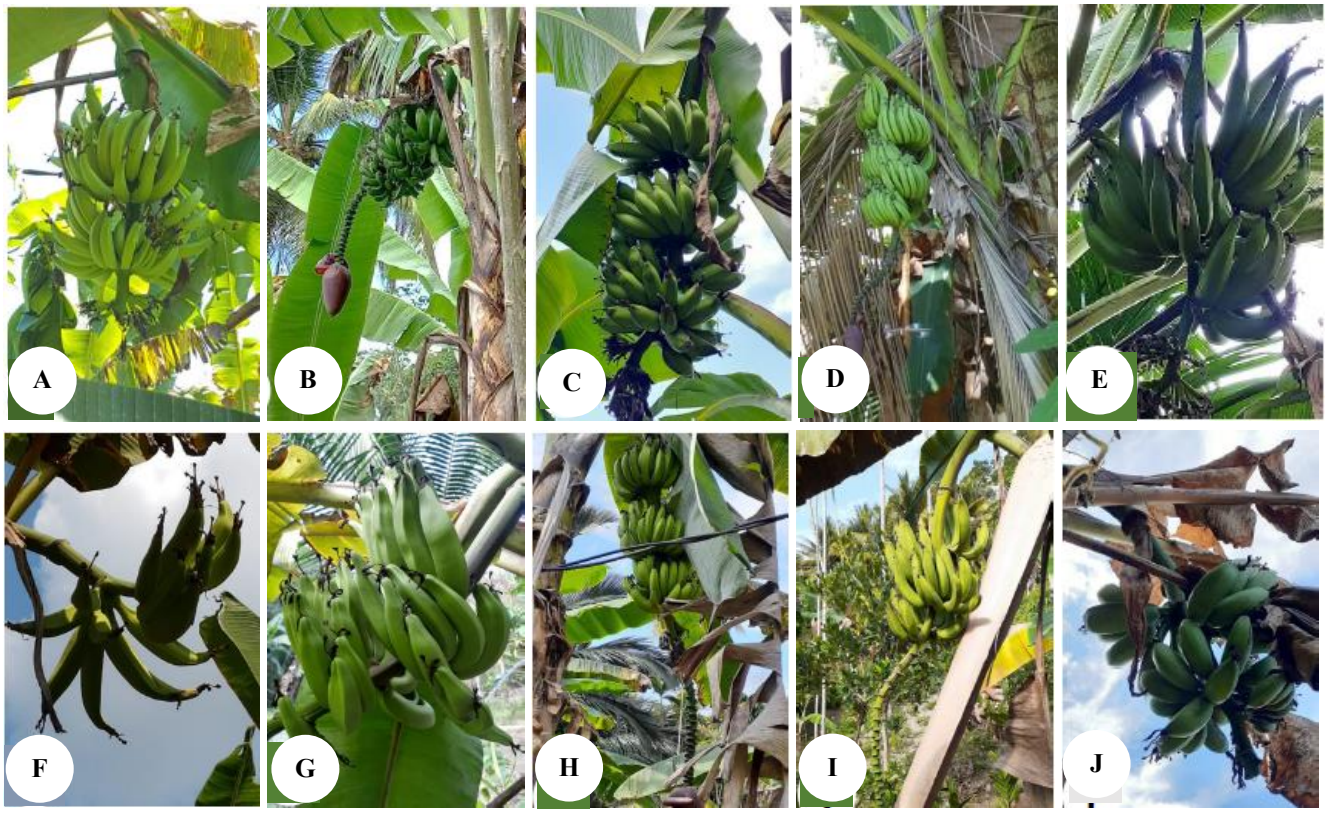

Figure 4. The Sentani community uses local banana varieties. A. *Keija*, B. *Aomang*, C. *Emfofo*, D. *Buwakhu*, E. *Anakhola*, F. *Remuhu*, G. *Molonsi*, H. *Olowambu*, I. *Wabulu*, J. *Hoyombi*

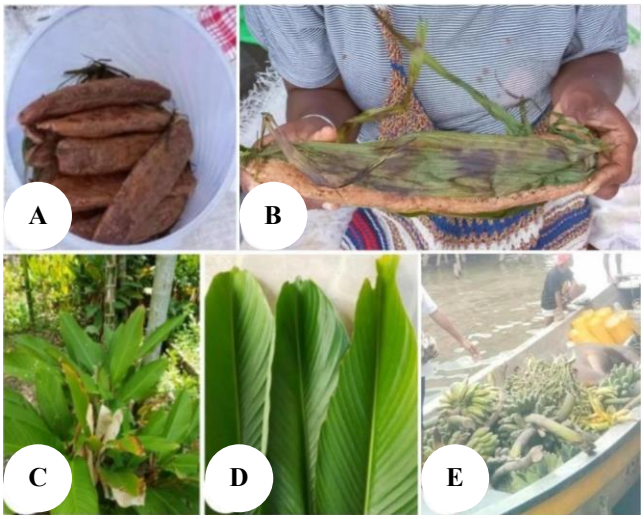

Figure 5. The use of Sentani local banana varieties. A. Grilled sago with *Aomang* bananas mixture, B. Grilled sago wrapped in wrapping leaves, C-D. Habitus and leaf blade of *Marantaceae*, E. Various varieties of local Sentani bananas in the mourning event

The cultivation of bananas is considered a longstanding tradition within the Sentani community. Local bananas are recognized and named based on their morphological characteristics (Figure 4). According to Purnamasari et al. (2020), Weihan et al. (2020), and Trimanto et al. (2022), when genetic factors exert a greater influence than environmental factors, variations in morphological characteristics among plants across diverse locations are constrained. However, plants cultivated under disparate environmental conditions exhibit a broader spectrum of morphological traits when environmental factors hold a more prominent sway than genetic factors. The extensive diversity observed in bananas exacerbates the challenge of encountering instances where distinct genomes share identical nomenclature.

The genus *Musa* has 66 species worldwide and is native to Southeast Asia, considered the main center of banana diversity. The species was originally domesticated in this region. Furthermore, 12 species were recorded with various cultivars, and only 20 varieties (landraces) were registered in Indonesia (Widjaja et al. 2014; Mukhoyyaroh and Hakim 2020).

The genus *Musa* is divided into five sections, namely *Australimusa* (2n=20), *Callimusa* (2n=20), *Ingentimusa* (2n=14), *Musa*/*Eumusa* (2n=22), and *Rhodochlamys* (2n=22). Wild and cultivated bananas (edible bananas) originated from the *Eumusa* section. Cultivated bananas are devoid of seeds, while their wild counterparts typically possess seeds with a modest quantity of fruit flesh and tend to thrive within forested areas or at the fringes of such environments. The wild banana species include *Musa acuminata* Colla (genome A) and *Musa balbisiana* Colla. Currently, the B genome is the ancestor of cultivated bananas (Ortiz and Swennen 2014; Poerba et al. 2016).

There are at least 15 varieties of *M. acuminata* in Indonesia, which are distributed from the western part to the eastern part. Bananas have developed into various varieties (diploid AA and triploid AAA) and hybridized with *M. balbisiana* to become AAB and ABB. Among the myriad cultivars documented worldwide, Indonesia contains an impressive assemblage of over 200 indigenous varieties cultivated across its expansive territory. These cultivars remain in their pristine state, untouched by deliberate enhancement or selective breeding processes (Notanubun and Karuwal 2014; Poerba et al. 2016; Trimanto et al. 2022; Zebua et al. 2023).

The Sentani community recognizes 10 local banana varieties based on fruit characteristics. As food, local bananas are sold in traditional markets around Jayapura between 20,000-50,000 IDR per pile (1 USD = 16,500 IDR), while a bunch is sold for 10,000-30,000 IDR. Based on the local wisdom of the Sentani community, local bananas are used as food, a delivery tool in a marriage proposal ceremony, a delivery tool at a mourning event, and the first plant when farmers want to start a new garden (Figure 5). In traditional restaurants, *Keija* bananas are processed by boiling, then served together with fried tilapia fish (*Oreochromis mossambicus* (Peters, 1852)) covered with tomato sauce (*Solanum lycopersicum* L.) and chili (*Capsicum frutescens* L.), boiled taro (*Colocasia esculenta* (L.) Schott) finely ground and mixed with grated coconut (*Cocos nucifera* L.), and sauteed papaya flowers (*Carica papaya* L.) and water spinach (*Ipomoea aquatica* Forssk.).

Keija is served using unripe bananas (*mengkal*), and according to the Sentani community, the half-ripe fruit has a better taste and is not too sweet, while the ripe *Keija* tastes sour. *Keija's* dish emerges as highly compatible with individuals harboring an aversion to rice consumption. This compatibility is attributed to the harmonious amalgamation of *Keija* bananas and taro (*C. esculenta*), which is a viable surrogate for the conventional rice offering. According to Putri et al. (2015), bananas, consumed ripe or unripe, are one of the most significant sources of calories. Bananas with yellow and orange flesh are also rich in provitamin A and other carotenoids. The fruits have the potential to overcome muscle fatigue due to the simple and complex carbohydrates as an energy source. Bananas contain carbohydrates in the form of sucrose, fructose, glucose, and fiber (Wulandari 2014; Putri et al. 2015). Furthermore, bananas garner recommendations as a favored fruit amongst athletes due to their substantial carbohydrate content and a rich complement of B vitamins. This unique nutritional profile facilitates the expeditious provision of energy, catering to the swift demands of athletic endeavors (Syarif et al. 2017).

The presentation of bananas with papaya flowers in the Sentani community is a traditional vegetable preparation. The flowers of *C. papaya* are used as fresh vegetables to complement the diet of society and support higher levels of individual growth. They have medicinal properties and can prevent cancer, improve digestion and appetite, and treat heart disorders (Yogiraj et al. 2014; Bergonio and Perez 2015; Abhishek et al. 2020; Zhang et al. 2022). The tannins and flavonoids in papaya flowers can act as antioxidants that scavenge free radicals from the body. The consumption helps the body neutralize free radicals and modulate the immune system. Papaya flowers and leaves are consumed as fresh vegetables in most parts of Indonesia (Putri et al. 2015).

Besides *Keija*, the Sentani community also uses *Aomang* and *Hoyombi*, which taste better when processed together with sago flour (*Metroxylon* sago), known as *Ouw* (grilled banana sago). The process involves the preparation of dried sago flour, which is sifted before being skillfully combined with either *Aomang* or *Hoyombi*, accompanied by grated coconut. Thorough mixing ensues to ensure proper integration, and the resulting dough is thoughtfully enveloped within a leaf wrapper, completing the procedure. In the Sentani language, the wrapping leaves are called *phothofhe* (Marantaceae) (Figure 3). Subsequently, the dough is steamed until cooked, then dried over coals, and served with tea or coffee. This food is often found in the Sentani traditional market in the morning with *Remuhu*. The culinary process entails steaming the ingredients, which are combined with freshly grated coconut and ultimately served alongside a steaming cup of tea or coffee. This indigenous leaf, used for wrapping food, is cultivated predominantly within the premises of residential compounds. The Sentani community utilizes these leaves as a primary medium for packaging victuals, often engaging in their commercial exchange within traditional markets. According to Ng (2015), in rural Sarawak, leaves from the Marantaceae are used to wrap rice.

Bananas play a significant role in various traditional cultural events, including proposals, weddings, and funerals. In the proposal ceremony, the woman's family will bring delivery materials in the form of their garden crops, such as bananas (Figure 3). Various varieties are brought to the male family, and the local Sentani varieties have a very important value compared to the introduced varieties. Local Sentani bananas are served to distinguished guests, for example, *ondofolo* (tribal chief) (Zebua et al. 2023).

Proximate analysis

The results of the proximate analysis of five samples of bananas based on the local name are shown in Table 3. The protein levels in the varieties showed significant differences ($p < 0.05$) with the local names *Buwakhu*, *Emfofo*, *Hoyombi*, *Keija*, and *Remuhu*. Protein levels from the highest to the lowest were found in bananas with local names *Hoyombi*, *Keija*, *Remuhu*, *Emfofo,* and *Uwakhu*. Hapsari and Lestari (2016) and Hasanah et al. (2017) showed that the protein content of bananas varied among cultivars. Banana protein content is generally in the range of 1.22-3.4% (Annor et al. 2016; Hapsari and Lestari 2016; Oyeyinka and Afolayan 2019). Vegetable protein is known to replace meat due to its higher nutritional and environmental benefits. Studies showed that consuming a diet rich in plant-based protein could improve kidney function (Bernier-Jean et al. 2021), prevent metabolic dysfunction (Chalvon-Demersay et al. 2017), improve physical performance (Gazzani et al. 2019), and reduce the risk of developing various chronic diseases (Lynch et al. 2018). Additionally, the production of vegetable

protein saves resources and does not damage the environment, with lower greenhouse gas emissions compared to raising animals (Bryant 2022).

The fat content among three of the five local Sentani banana cultivars tested (*Uwakhu*, *Keija*, and *Emfofo*) showed no significant difference ($p > 0.05$), with values of 0.11, 0.16, and 0.22%, respectively. In contrast, significant differences in fat content were observed in *Hoyombi* (3.06%) and *Remuhu* (1.86%). These findings align with previous research by Annor et al. (2016), Hapsari and Lestari (2016), Hasanah et al. (2017), and Oyeyinka and Afolayan (2019), who consistently report that fat content is influenced by cultivar. Specifically, Oyeyinka and Afolayan (2019) reported banana fat content ranging from 0.15-1.24%, while Annor et al. (2016) and Hasanah et al. (2017) found lower ranges of 0.0-0.3% and 0.33-0.34 g/100 g, respectively. Notably, the fat content of the *Uwakhu*, *Keija*, and *Emfofo* cultivars in this study was lower than the values reported by Annor et al. (2016) and Hasanah et al. (2017).

The results of the moisture test (Table 1) showed that the local banana cultivars *Sentani Keija* and *Emfofo* did not show a significant difference ($p < 0.05$). However, Keija and Emfofo showed significant differences ($p > 0.05$) with *Uwakhu*, *Remuhu,* and *Hoyombi*. Successively starting from the highest moisture content, local banana cultivars Sentani are *Uwakhu*, *Remuhu*, *Keija, Emfofo*, and *Hoyombi*. Banana cultivars affect the water content. According to Hasanah et al. (2017), significant differences in water content exist among the *Barangan, Masak Hijau*, and *Singapore* cultivars. Moisture content in food greatly influences the quality of food products.

Analysis of ash content in five local banana cultivars of Sentani showed that bananas with local names *Emfofo*, *Uwakhu*, and *Remuhu* were not significantly different, as well as Uwakhu, Remuhu, Keija, and *Hoyombi* did not show significant differences. However, *Emfofo* was significantly different from *Keija* and *Hoyombi*. Ash content is known to affect mineral content such as Mn and Zn in fruit (Milošević and Milošević 2012).

The crude fiber content of bananas with local names *Emfofo* and *Hoyombi* did not show a significant difference. At the same time, the two cultivars showed significant differences with banana cultivars *Uwakhu, Remuhu,* and *Keija*. The highest to lowest fiber content of Sentani banana cultivars was *Hoyombi, Emfofo, Keija, Remuhu*, and *Uwakhu*, respectively (Table 1). Compared to other banana cultivars, such as *Barangan*, *Masak Hijau,* and *Singapore* (Hasanah et al. 2017), the crude fiber content of local banana cultivars *Sentani Hoyombi, Emfofo,* and *Keija* showed higher values. Fiber, as a supplement, is known to alter the texture, consistency, rheological properties, and sensory characteristics of food products (Collar et al. 2009).

There was no significant difference in total carbohydrate content in local banana cultivars *Sentani Uwakhu*, *Keija*, and *Emfofo*. Meanwhile, the three banana cultivars were significantly different from the *Remuhu* and *Hoyombi* cultivars (Table 1). The carbohydrate composition of bananas changes greatly during ripening. Starch is the main component of unripe bananas (Aquino et al. 2016). There was also no significant difference in total carbohydrate content between *Buwakhu*, *Emfofo,* and *Keija*, which were significantly different from *Hoyombi* and *Remuhu*. The carbohydrate composition changes greatly during ripening, and starch is the main component of unripe bananas (Phillips et al. 2021). Sufficient energy reserves after consuming bananas during exercise, specifically long-duration exercise, can prevent fatigue (Dewantari et al. 2022). Complex carbohydrates such as glucose, fructose, and sucrose will be converted into glucose in the body. The glucose is then stored in the form of glycogen in the liver by 18-22% and in the muscles by ± 80% (Wulandari et al. 2018).

In general, this study shows that the Sentani community has planted local varieties of bananas recognized based on the morphological characteristics, pseudo stem, and leaves. However, the prevalence of indigenous Sentani bananas is presently dwindling, largely attributed to the transformation of land for residential purposes. This decline in cultivation among the populace is a cause for concern, as these bananas hold dietary significance and possess a profound cultural essence. They assume a pivotal role in ceremonial contexts such as proposals, marriages, and commemorations of deceased individuals. Within these significant cultural junctures, the indigenous Sentani bananas take precedence, symbolizing a gesture of honor and respect towards esteemed individuals. Based on the proximate analysis of local Sentani bananas, five samples had significant differences in protein content. Meanwhile, the discerned distinctions were not deemed statistically significant concerning fat, water, ash, and carbohydrate content.

Table 3. Results of proximate analysis of five samples of Sentani local bananas

Local name (Sentani)	Protein (%)	Fat (%)	Moisture (%)	Ash (%)	Crude fiber (%)	Total Carbohydrate (%)
Buwakhu	0.58 ± 0.02^{e}	0.11 ± 0.01^{c}	71.69 ± 0.29^{a}	0.88 ± 0.07^{abc}	0.14 ± 0.01^{d}	26.74 ± 0.29^{a}
Emfofo	1.52 ± 0.00^{d}	0.16 ± 0.01^{c}	68.16 ± 0.01^{c}	0.92 ± 0.01^{ab}	2.83 ± 0.01^{a}	26.41 ± 0.03^{a}
Hoyombi	3.06 ± 0.00^{a}	0.81 ± 0.01^{a}	67.66 ± 0.03^{d}	0.82 ± 0.01^{c}	2.90 ± 0.01^{a}	24.75 ± 0.04^{c}
Keija	2.03 ± 0.00^{b}	0.22 ± 0.05^{c}	68.22 ± 0.02^{c}	0.82 ± 0.01^{c}	2.19 ± 0.01^{b}	26.53 ± 0.07^{a}
Remuhu	1.86 ± 0.00^{c}	0.50 ± 0.01^{b}	69.53 ± 0.01^{b}	0.91 ± 0.01^{abc}	1.13 ± 0.01^{c}	26.07 ± 0.02^{b}

Note: The measurement results of the proximate analysis were the mean of 3 replications ± standard deviation. Values with different letters in the same column differ significantly at $p < 0.05$

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A bibliometric analysis of research gaps on ritual plants within ethnobotanical studies in Indonesia

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[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang. Jl. Simpang Bogor No.19, Malang 65145, East Java, Indonesia. Tel./fax.: +62-341-551312, ♥email: sulisetijono.fmipa@um.ac.id

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Manuscript received: 9 April 2025. Revision accepted: 16 June 2025.

Abstract. *Sudirgayasa IG, Sulisetijono, Mahanal S, Gofur A, Surata IK, Sudiana IM, Maduriana IM. 2025. A bibliometric analysis of research gaps on ritual plants within ethnobotanical studies in Indonesia. Asian J Ethnobiol 8: 158-170.* Ethnobotany plays a crucial role as a bridge between traditional knowledge and modern science, exploring the deep and long-standing relationship between humans and plants. In Indonesia—a country rich in both biodiversity and cultural diversity—ethnobotany holds a vital place in safeguarding ancestral heritage, such as herbal remedies, traditional rituals, and indigenous agricultural practices. These traditions not only enrich the nation's identity but also offer sustainable alternatives for the future. This analysis aims to map research trends and identify knowledge gaps related to ethnobotany in Indonesia. The findings are expected to serve as a reference for conservation programs that preserve local wisdom throughout the country. This study employed a bibliometric analysis. Scientific publication data were obtained from the Scopus database over the past decade. The keywords used included *ethnobotany, ethnobotanic, ethnobotanical, Indonesia, Indonesian, ritual,* and *rituals.* Data were analyzed using VOSviewer and Microsoft Excel. The analysis revealed several gaps that need to be addressed. First, the most popular topic in ethnobotanical research in Indonesia over the past decade has been medicinal plants. In contrast, research on ritual plants remains minimal—comprising less than 10% of all ethnobotanical studies—with an average of only two publications per year and a stagnant trend. Second, the digitalization of ethnobotanical data on internet-based platforms is still underdeveloped. The visibility and popularity of ritual plant studies should be enhanced through increased global collaboration, funding support, and sustainable conservation policies. Digitalization efforts should be improved by developing websites, mobile applications, social media platforms, and mapping plant distribution using Geographic Information System (GIS) tools or Google MyMaps. The education system should also be engaged by promoting the integration of ethnobotanical themes and values through both intra-disciplinary and interdisciplinary approaches.

Keywords: Bibliometric analysis**,** ethnobotanical, gap, Indonesia, ritual plants

Abbreviations: AI: Artificial Intelligence, CSV: Comma Separated Values, VOSviewer: Visualization of Similarities Viewer

INTRODUCTION

Ethnobiology plays a vital role in maintaining harmony between humans and nature by exploring traditional knowledge passed down orally through generations (Albuquerque and Alves 2016). It is not merely the study of how people utilize living organisms around them, but also an exploration of how values, beliefs, and cultural identities are shaped through interactions with the environment. Amid the rapid pace of modernization that often overlooks local wisdom, ethnobiology serves as a bridge connecting the past to the future, uniting science and spirituality within a single narrative of life (Wolverton 2013; Lotero-Velásquez et al. 2024). By understanding ethnobiology, we are not only preserving biodiversity but also nurturing the collective human spirit that has long evolved in tandem with the natural world (Turner et al. 2022; Baghersad et al. 2024). One of the main branches of ethnobiology is ethnobotany, which specifically focuses on the relationship between humans and plants various aspects of life (Albuquerque et al. 2017). This field examines how various cultures perceive, use, and manage plant resources for food, traditional medicine, construction materials, cultural rituals, and as symbols of belief (Siswanto and Batoro 2019; Singh et al. 2025). Through ethnobotany, we can understand and preserve traditional knowledge while contributing to the conservation of natural resources, especially plants.

As a tropical country, Indonesia possesses abundant biodiversity (Rintelen et al. 2017) alongside a rich cultural heritage. Since ancient times, Indonesian communities have lived in harmony with nature, guided by local wisdom passed down through generations (Kubontubuh 2023). In this context, ethnobotany holds a unique and profound role, reflecting the nation's extraordinary biological and cultural diversity (Hidayat et al. 2018; Afentina et al. 2020; Jannaturrayyan et al. 2020; Rambey et al. 2021). Beneath the canopy of dense tropical forests and within traditionally managed gardens lies a wealth of indigenous knowledge—ranging from medicinal plants and food sources to flora imbued with spiritual significance in ritual ceremonies.

More than a scientific discipline, ethnobotany in Indonesia serves as a medium for preserving local wisdom, reinforcing cultural identity, and sustaining the harmonious relationship between humans and nature. In the face of modernization, ethnobotany reminds us that plants are not merely natural resources, but vital components of the collective consciousness that shapes the holistic and meaningful way of life among the Indonesian people (Marsandi et al. 2025). One important branch of this field is ritual ethnobotany, which explores the role of plants in religious and ceremonial contexts.

Ritual plant ethnobotany plays a crucial role in preserving traditions and conserving the environment in the modern era (Geng et al. 2017). It serves as an effective approach to protecting rare flora with spiritual and ritual significance (Cornelius and Van Wyk 2025). This practice strengthens the cultural identity of indigenous communities, enhances ecological awareness, and maintains the balance between humans and nature amid rapid modernization (Jigme and Yangchen 2022). Furthermore, studies on ritual plant ethnobotany open opportunities for innovation in various fields, including the development of creative industries, cultural tourism, biodiversity conservation, education and research, local economic empowerment, and traditional healing (Quiroz et al. 2016; Rahayu et al. 2023).

However, does the research trend in ritual plant ethnobotany in Indonesia align with expectations? To answer this question, a bibliometric analysis might be useful as an initial step to uncover research patterns, trends, and unexplored knowledge gaps related to ethnobotany in Indonesia. The bibliometric approach provides a comprehensive overview of the most influential research contributions, scientific collaboration networks, and dominant topics within a specific field of study (Manterola et al. 2024; Sharma et al. 2024a). Bibliometric analysis serves not merely as a tool for tracking publication trends, but as a compass for understanding how knowledge about the intricate relationship between humans and plants evolves and gains recognition across the globe (Donthu et al. 2021). It enables researchers to trace intellectual trajectories, uncover underexplored themes, and foster cross-cultural and interdisciplinary collaborations (Ochsner 2021). Bibliometric studies help ensure that traditional knowledge, such as medicinal plant practices or the ritual use of flora, is not only documented but also valued within the global academic landscape. Beyond numbers and citations, bibliometrics in ethnobotany is an effort to preserve the collective human memory of nature, ensuring that this cultural and ecological legacy remains alive and relevant in addressing future challenges. Specifically, this bibliometric analysis aims to: (i) Map the publication trends of ethnobotanical studies in Indonesia, (ii) Identify the most productive journals related to ethnobotanical research in Indonesia, (iii) Identify the most productive affiliations involved in ethnobotanical research in Indonesia, (iv) Identify the most prolific authors contributing to ethnobotanical studies in Indonesia, (v) Identify the most productive countries in the field of ethnobotanical research in Indonesia, (vi) Map the most prominent subject areas within ethnobotanical studies in Indonesia, (vii) Identify the most active funding sponsors supporting ethnobotanical research in Indonesia, (viii) Highlight the most influential scientific publications on ethnobotany in Indonesia, (ix) Map national and international author collaborations in ethnobotanical research in Indonesia, (x) Identify popular keywords and emerging topics related to ethnobotanical studies in Indonesia, (xi) Provide recommendations and insights to address knowledge gaps in future research.

MATERIALS AND METHODS

Study area

The primary study area of this bibliometric analysis encompasses all ethnobotanical studies conducted in Indonesia. All studies analyzed, whether conducted by Indonesian or international researchers, focus on the utilization of plants by local communities across various regions of Indonesia, ranging from western areas such as Sumatra and Kalimantan to eastern regions such as Maluku and Papua. For comparison, a global-scale ethnobotanical analysis was also conducted to contextualize the trends of ethnobotanical study in Indonesia within the broader international landscape.

Procedures

A bibliometric approach was employed to analyze scientific publications related to ethnobotany in Indonesia. This method was selected in alignment with the study's objective of identifying research trends, scientific collaborations, and popular topics (Donthu et al. 2021; Sharma et al. 2024b). We adopted the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 flow diagram in the data search strategy (Figure 1). Scientific publication data were retrieved from the Scopus database. The data search was conducted using relevant keywords, including ethnobotany, ethnobotanic, ethnobotanical, Indonesia, Indonesian, ritual, and rituals. Additionally, specific filters were applied, such as a 10-year time frame (2015-2025), and types of publications limited to journal articles, conference papers, and review papers (Table 1). The collected data were then exported in Comma-Separated Values (CSV) format for further analysis.

Table 1. Summary of data search strategy

Category	Criteria
Database	Scopus
Search query	((TITLE-ABS-KEY(ethnobotany OR ethnobotanic OR ethnobotanical) AND TITLE-ABS-KEY(indonesia OR indonesian)) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp") OR LIMIT-TO (DOCTYPE,"re")))
Year of publication	2015- March 2025
Documents type	Article, review, and conference paper
Study area	All study area
Data export format	Comma-Separated Values (CSV)

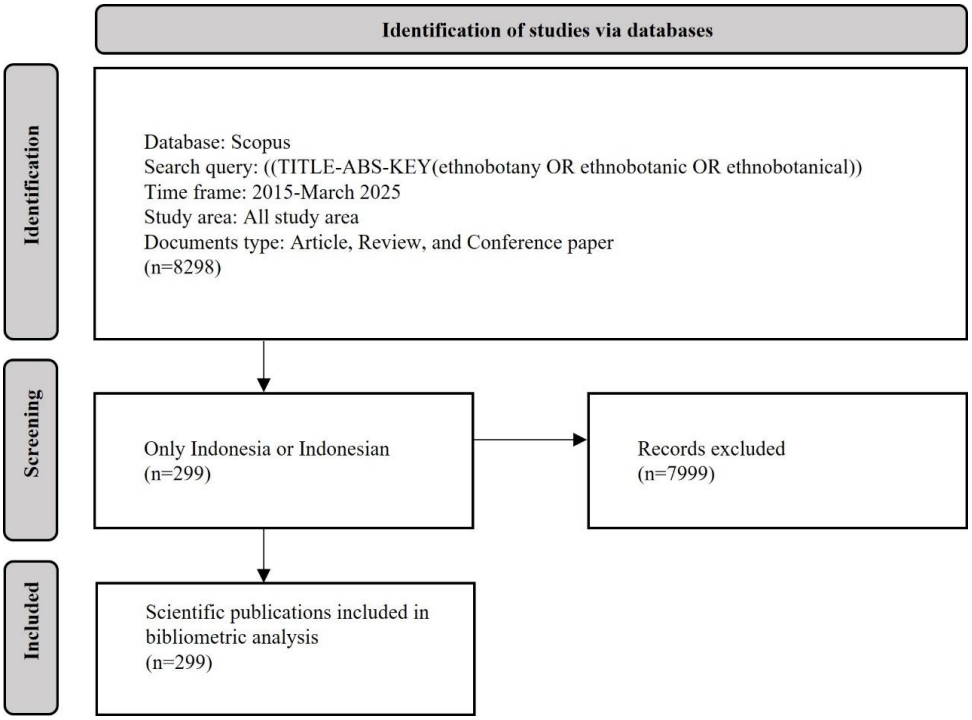

Figure 1. PRISMA flow diagram on the identification and screening of scientific publications

Table 2. Number of scientific publications on ethnobotany in the last decade

Year	Ethnobotany			
	Global	Global ritual	Indonesia	Indonesian ritual
2015	536	15	7	2
2016	571	24	12	1
2017	557	17	18	2
2018	581	15	20	1
2019	698	25	24	3
2020	903	25	38	4
2021	965	22	41	1
2022	983	35	28	2
2023	1095	25	49	3
2024	1179	36	57	5
2025	230	10	5	0
Total	8298	249	299	24
Average	754	23	29	2

Data analysis

The collected scientific publications were analyzed using several key parameters, including publication trends, most productive journals, leading affiliations, top contributing authors, most active research fields, funding sources, patterns of author collaboration, and commonly studied topics. These parameters were employed to identify gaps between research expectations and actual findings, providing a strategic foundation for shaping future directions in ethnobotanical research. The data were processed and analyzed using VOSviewer and Microsoft Excel. VOSviewer was applied to examine author collaboration networks and to visualize frequently occurring keywords. Microsoft Excel was used to organize data, generate tables and graphs, and perform initial data management prior to further analysis in VOSviewer.

RESULTS AND DISCUSSION

Trends in ethnobotany publications in Indonesia

In general, the number of scientific publications related to ethnobotany in Indonesia has shown an increasing trend over the past decade (Table 2; Figure 2). The average number of publications is 29 documents per year, with the highest number recorded in 2024, total 57 documents. However, publications on ritual ethnobotany in Indonesia have remained stagnant, with an average of only two documents per year. This number is significantly lower compared to global ethnobotany publications, which average 754 documents per year.

Most productive journals

The ten most productive journals and conferences publishing scientific research on ethnobotany in Indonesia over the past decade are presented in Figure 3. Two of these journals are classified as Quartile 1 (Q1) according to the Scimago Journal and Country Rank website. The two journals are Ethnobotany Research and Applications and the Journal of Ethnopharmacology. Biodiversitas (Q2) ranks first, with 102 documents. This is followed by IOP Conference Series: Earth and Environmental Science in second place with 29 documents. The third position is held by Ethnobotany Research and Applications with 16 documents.

Information on the most active journals plays a crucial role in mapping the development of scientific knowledge in specific fields such as ethnobotany. By recognizing the most productive journals, researchers can identify key sources frequently cited, understand emerging research trends, and select reputable journals that are most suitable for publishing their work. Moreover, this information is

valuable for fostering strategic scientific collaborations and enhancing the visibility of research outputs at both national and international levels.

Most productive affiliations

The ten most productive affiliations in scientific publications on ethnobotany in Indonesia over the past decade are presented in Figure 4. The National Research and Innovation Agency (Badan Riset dan Inovasi Nasional) ranks first, with 28 publications. The Indonesian Institute of Sciences (LIPI), which is now part of a Research Organization (RO) under the National Research and Innovation Agency (BRIN) ranks second with 26 publications. The third position is shared by Institut Pertanian Bogor and Universitas Padjadjaran, each contributing 24 publications.

This information plays a strategic role in advancing scientific development and fostering research collaboration. This data is useful for identifying leading institutions in the field, serving as a reference for researchers seeking academic partnerships, pursuing further studies, or initiating joint research projects. Additionally, it aids funding agencies and policymakers in directing research support based on institutional productivity and impact. For students and early-career researchers, highly active affiliations can be an important consideration when selecting institutions for academic training or professional growth. Furthermore, mapping institutional contributions can help reveal research gaps across regions or organizations, thereby encouraging more equitable development of research capacity in ethnobotany throughout Indonesia.

Most productive authors

The ten most productive authors in scientific publications on ethnobotany in Indonesia over the past decade are presented in Figure 5. Johan Iskandar ranks first, with 22 publications. The second and third positions are held by Marina Silalahi and Adi Bejo Suwardi, each contributing 15 publications.

This information holds strategic value in building a robust and sustainable research ecosystem. By identifying active researchers, we can recognize the individuals driving the advancement of knowledge in this field. This data not only serves as an academic reference but also opens opportunities for collaboration, idea exchange, and cross-generational learning among researchers. For students and early-career researchers, the works of highly productive authors can serve as a rich source of inspiration and learning, while also highlighting emerging research directions and trends. Thus, mapping the most active authors helps foster a more dynamic, interconnected scientific community that is focused on collective progress.

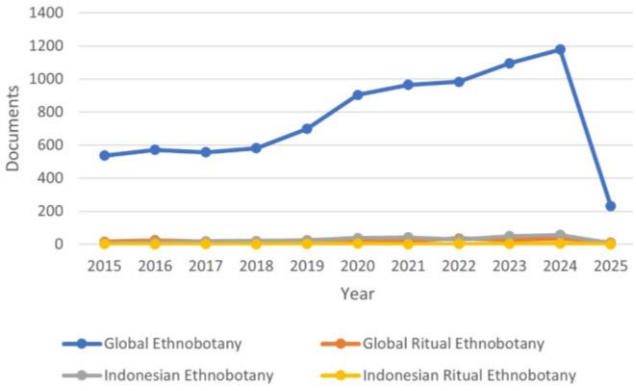

Figure 2. Trend of the number of scientific publications on ethnobotany in the last decade

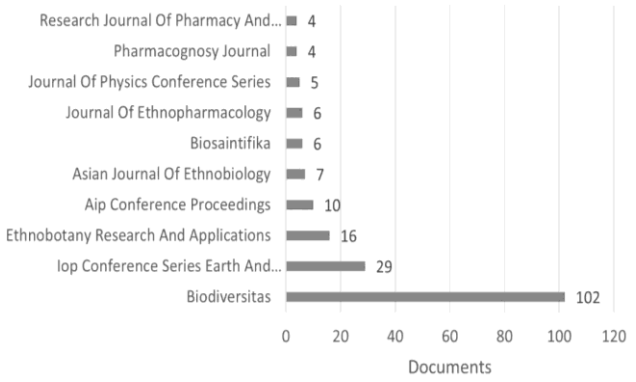

Figure 3. The most productive journals and conferences with scientific publications on ethnobotany in Indonesia in the last decade

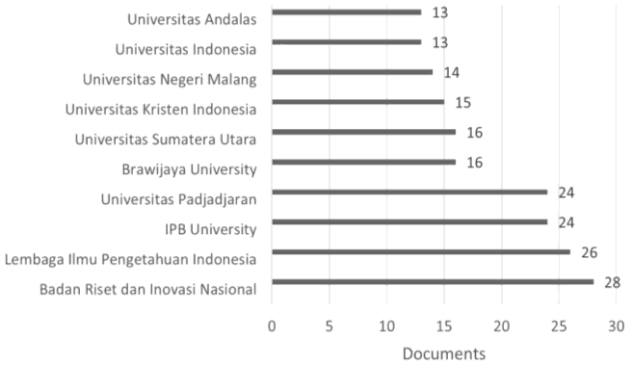

Figure 4. The most productive affiliations in scientific publications on ethnobotany in Indonesia in the last decade

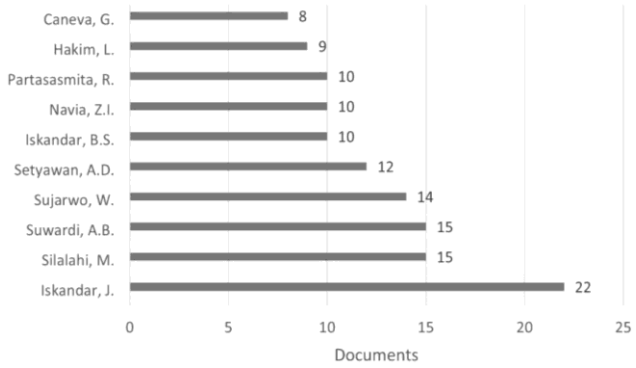

Figure 5. The most productive authors in scientific publications on ethnobotany in Indonesia in the last decade

Figure 6. The ten most productive countries in ethnobotanical studies in Indonesia

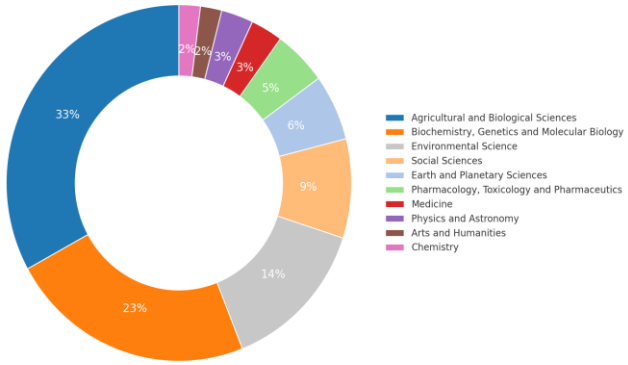

Figure 7. The most prevalent subject areas in scientific publications on ethnobotany in Indonesia in the last decade

Most productive countries

The distribution of the ten most productive countries in ethnobotanical studies in Indonesia is presented in Figure 6. Indonesia ranks first with 279 documents or 84.80%. It is followed by Italy and Malaysia, each with 9 documents or 2.74%. Japan ranks fourth with 7 documents or 2.13%, while Australia is in fifth place with 5 documents or 1.52%. The remaining countries-France, India, Netherlands, South Korea, and Thailand-each contributed 4 documents or 1.22%.

This information plays a crucial role in providing insights into the global dynamics of scientific development. This data allows us to identify leading countries in ethnobotanical study and compare research contributions across nations, which in turn can strengthen international collaborations. By recognizing the countries producing the most publications, we can assess the research strengths and identify areas that may require more attention. Additionally, this information is valuable for governments and funding agencies in shaping policies that support research and in more effectively allocating resources.

Most productive subject area

The ten most productive subject areas in scientific publications on ethnobotany in Indonesia over the past decade are presented in Figure 7. Agricultural and Biological Sciences ranks first, with 186 documents (33%). Ethnobotanical studies are inherently multidisciplinary, involving various scientific disciplines. A multidisciplinary approach enables a broader and more holistic understanding of human-plant interactions.

This information provides valuable insights into the scope, direction, and interdisciplinary nature of research in ethnobotany. First, it helps identify the academic disciplines that contribute most significantly to ethnobotany. Second, it offers an overview of prevailing research focuses, such as medicinal plant conservation, traditional knowledge, or bioprospecting, which can serve as a reference for formulating research questions or selecting future study topics. Third, this information is useful for designing academic curricula, developing study programs, and establishing research centers aligned with academic and societal needs. Lastly, mapping the most productive subject areas enables greater synergy between disciplines to support the integrated and sustainable preservation of biodiversity and local wisdom.

Funding sponsor

The ten funding sponsors supporting scientific publications on ethnobotany in Indonesia over the past decade are presented in Figure 8. Universitas Padjadjaran ranks first, sponsoring ten documents. The Ministry of Research, Technology, and Higher Education of the Republic of Indonesia (Kementerian Riset Teknologi Dan Pendidikan Tinggi Republik Indonesia) ranks second, having funded nine publications. The third position is held by the Ministero dell'Istruzione, dell'Università e della Ricerca, which supported eight publications. In general, funding for ethnobotanical studies in Indonesia is primarily provided by government institutions through ministries and public universities.

This information plays a key role in guiding the sustainability and strategic direction of scientific inquiry in ethnobotanical studies. First, it allows for the identification of national and international institutions that actively support ethnobotanical studies. Second, this information serves as a practical reference for researchers seeking funding opportunities aligned with their research interests, while also helping them understand each sponsor's priorities and focus areas. Third, insights into funding patterns enable academic institutions and research centers to develop more targeted strategies that align with donor agendas. Furthermore, transparency in funding sources promotes accountability and reinforces ethical standards in scholarly publishing.

Most influential scientific publications

The ten most highly cited publications are presented in Table 3. The top position is held by Jadid et al. (2020) with a total of 102 citations, followed by Ansori et al. (2020) in second place with 96 citations. Rahmat et al. (2021) ranks third with 85 citations. This information highlights the most influential publications related to ethnobotanical research in Indonesia.

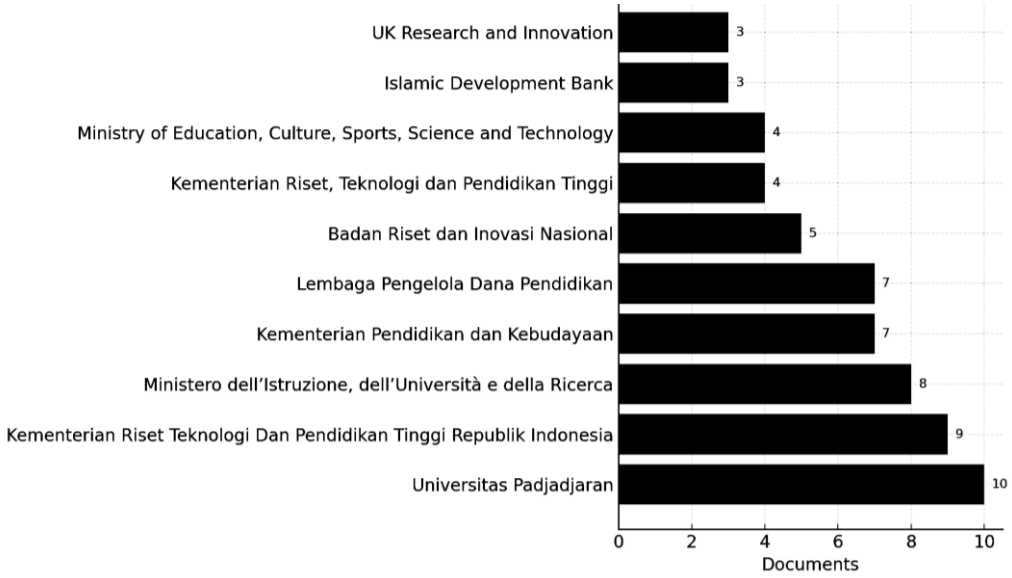

Figure 8. The funding sponsors in scientific publications on ethnobotany in Indonesia in the last decade

Table 3. The ten most influential publications on ethnobotany in Indonesia in the last decade

Rank	Author	Document title	Source	Total citations
1	Jadid et al. (2020)	An ethnobotanical study of medicinal plants used by the Tengger Tribe in Ngadisari Village, Indonesia	PLoS One	102
2	Ansori et al. (2020)	A review on medicinal properties of mangosteen (*Garcinia mangostana* L.)	Research Journal of Pharmacy and Technology	96
3	Rahmat et al. (2021)	Javanese turmeric (*Curcuma xanthorrhiza* Roxb.): Ethnobotany, phytochemistry, biotechnology, and pharmacological activities	Evidence-Based Complementary and Alternative Medicine	85
4	Silalahi et al. (2015)	The local knowledge of medicinal plants trader and diversity of medicinal plants in the Kabanjahe traditional market, North Sumatra, Indonesia	Journal of Ethnopharmacology	83
5	Sujarwo et al. (2015)	Ethnobotanical study of Loloh: Traditional herbal drinks from Bali (Indonesia)	Journal of Ethnopharmacology	78
6	Pawera et al. (2020)	Wild food plants and trends in their use: From knowledge and perceptions to drivers of change in West Sumatra, Indonesia	Foods	71
7	Suwardi et al. (2020)	Ethnobotany and conservation of indigenous edible fruit plants in South Aceh, Indonesia	Biodiversitas Journal of Biological Diversity	63
8	Sujarwo et al. (2016)	Ethnobotanical uses of neem (Azadirachta indica A.Juss.; Meliaceae) leaves in Bali (Indonesia) and the Indian subcontinent in relation with historical background and phytochemical properties	Journal of Ethnopharmacology	57
9	Supiandi et al. (2019)	Ethnobotany of traditional medicinal plants used by Dayak Desa Community in Sintang, West Kalimantan, Indonesia	Biodiversitas Journal of Biological Diversity	55
10	Silalahi and Nisyawati (2018)	The ethnobotanical study of edible and medicinal plants in the home garden of Batak Karo Sub-ethnic in North Sumatra, Indonesia	Biodiversitas Journal of Biological Diversity	50
Total				740
Average				74

This information is essential for understanding the core contributions that have shaped the field. Highly cited works often represent foundational studies or critical shifts in theoretical frameworks, methodologies, or empirical findings. For researchers, these publications serve as key references that provide a strong basis for developing well-informed research questions and frameworks. Additionally, identifying high-impact publications helps scholars recognize prevailing trends and directions in the discipline, enabling them to align their work with current scientific discourse. Such influential studies also foster interdisciplinary dialogue and broaden perspectives on issues related to traditional knowledge, biodiversity conservation, and sustainability at both local and global levels.

National and international author collaboration

The results of the author collaboration network analysis using VOSviewer are presented in Figure 9. National collaborations among authors tend to occur within the same institution. Among the six author clusters, only two clusters exhibit cross-collaboration. On the other hand, international author collaboration remains limited. The countries most frequently collaborating with Indonesian researchers include Japan, Australia, Italy, and Malaysia (Figure 10).

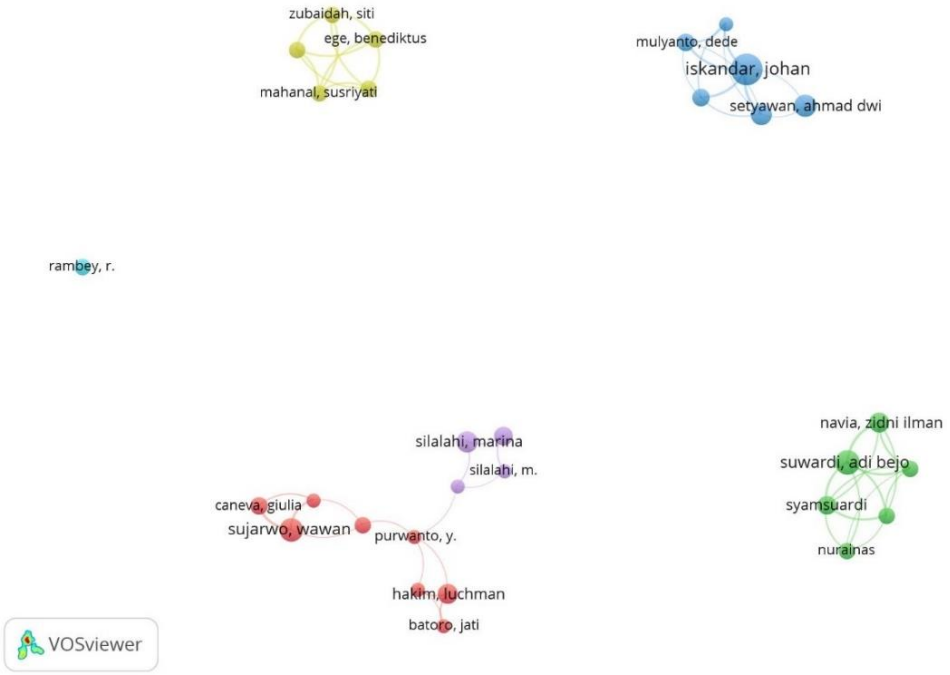

Figure 9. Diagram of collaboration among authors in publications on ethnobotany in Indonesia in the last decade

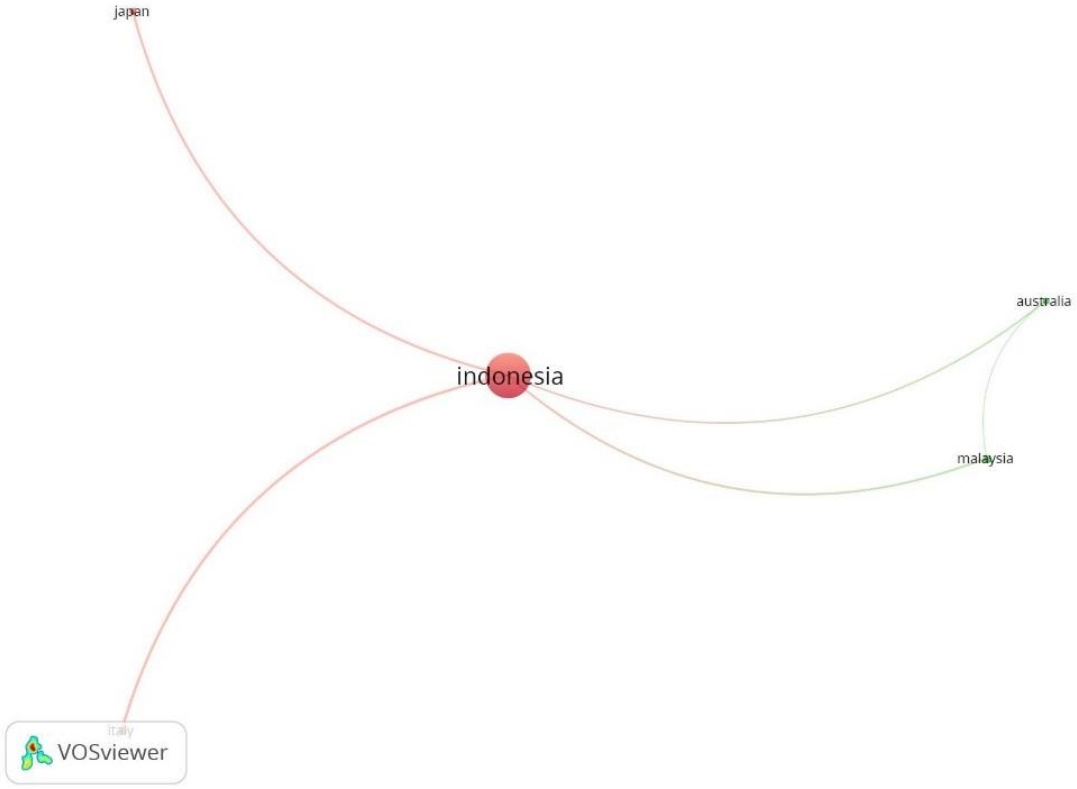

Figure 10. Diagram of collaboration among countries in publications on ethnobotany in Indonesia in the last decade

Keyword analysis and popular topics

The results of keyword analysis using VOSviewer are presented in Figures 11, 12, and 13. Based on the Network Visualization diagram, ethnobotanical research in Indonesia is categorized into three main clusters: ethnoculture, ethnomedicine, and ethnochemistry. The Overlay Visualization diagram indicates that the latest research topics in Indonesian ethnobotany focus on medicinal plants and local wisdom conservation. Furthermore, according to the Density Visualization diagram, the most extensively studied topic in Indonesian ethnobotany is medicinal plants, as reflected by dominant keywords such as medicinal plants, ethnopharmacology, and traditional medicine.

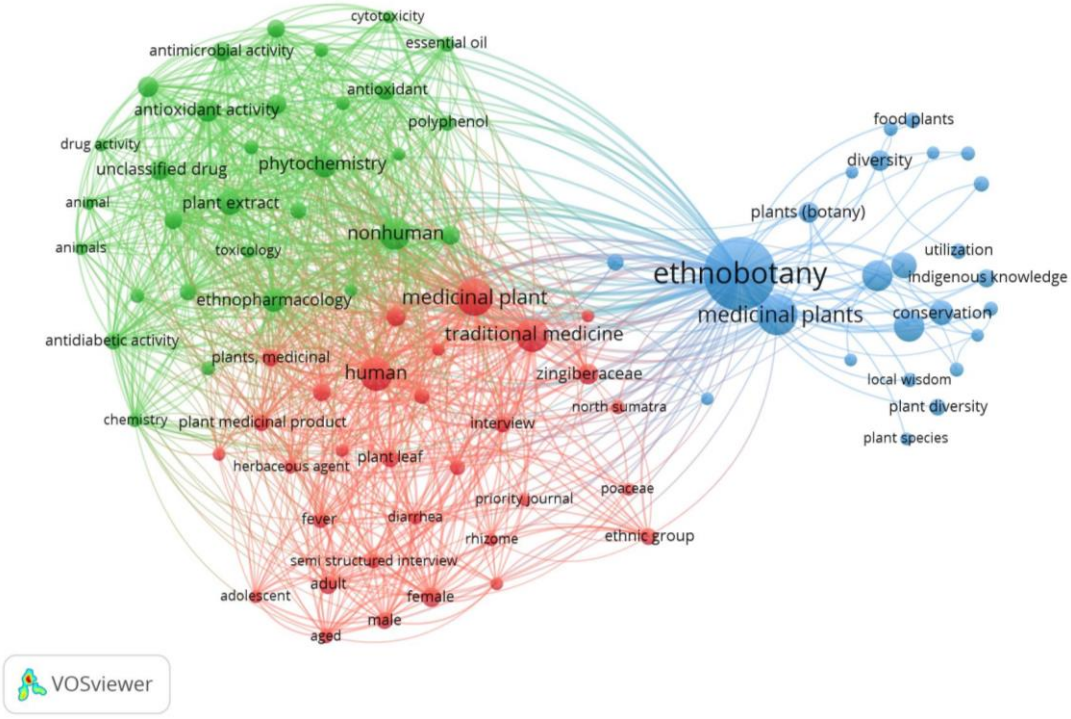

Figure 11. Network visualization of ethnobotanical publications in Indonesia in the last decade

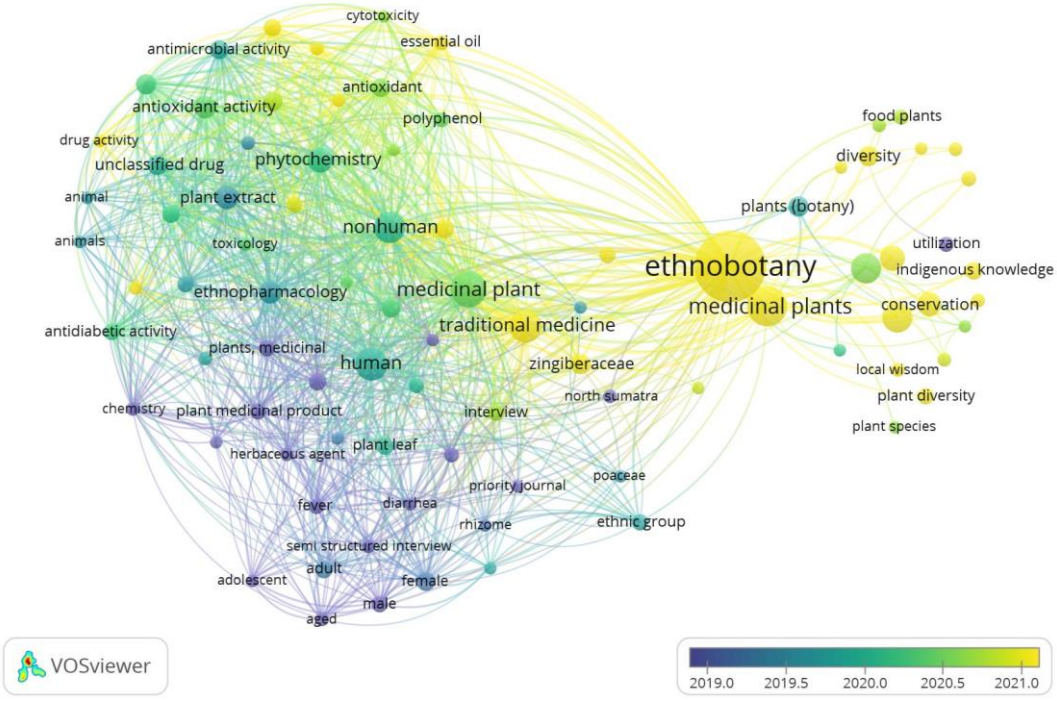

Figure 12. Overlay visualization of ethnobotanical publications in Indonesia in the last decade

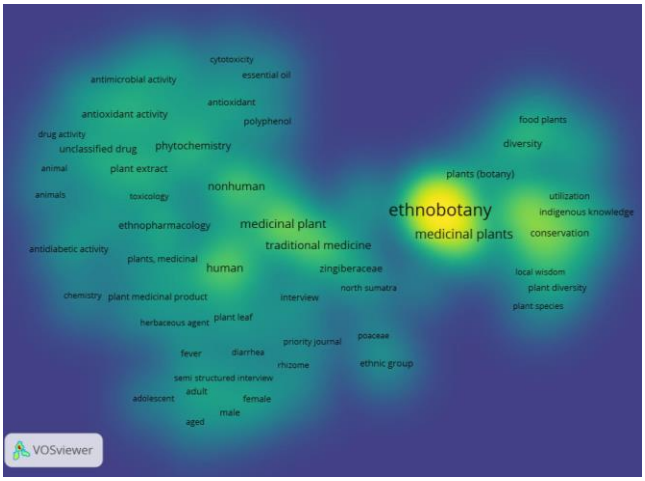

Figure 13. Density visualization of ethnobotanical publications in Indonesia in the last decade

Discussion

The gap in ethnobotanical studies on ritual plants

Research publications on ritual ethnobotany in Indonesia have remained stagnant over the past decade, with an average of only two documents per year. Ethnobotanical studies on medicinal plants are significantly more popular than those on ritual plants, both in Indonesia and globally (Sharma et al. 2024c; Vats et al. 2024). Several factors contribute to this gap. Medicinal plants are widely accepted due to their therapeutic applications, whereas ritual plants are often linked to specific local beliefs, making their use less universally applicable (Staub et al. 2011; Dafni et al. 2020). Some ritual plants are considered sacred, leading to restricted access (Fatur 2020; Tatay and Merino 2023). Additionally, traditional medicinal plants can be developed into modern pharmaceuticals with high economic value (Chotchoungchatchai et al. 2012; Sarin et al. 2014), increasing the likelihood of funding and research proposal acceptance. This disparity also occurs on a global scale. The total number of scientific publications on the ethnobotany of ritual plants in the past decade is only 249 documents, averaging 23 documents per year. This number is significantly lower compared to studies on the ethnobotany of medicinal plants.

This gap poses a dilemma for a biodiversity and culturally-rich country like Indonesia. If this trend continues, it could threaten the preservation of local wisdom related to ritual plants. To address this issue, global-scale research on Indonesia's ritual ethnobotany must be strengthened. This can be achieved through enhanced international collaboration, digital and AI-based technology utilization, interdisciplinary approaches, increased funding support, and sustainable conservation policies (Chaachouaya et al. 2023; Chitakunye et al. 2023; Duche-Pérez et al. 2024).

The challenges in increasing the number of ethnobotanical publications focused on ritual plants in Indonesia are complex and multidimensional. One of the main barriers is the limited documentation of local knowledge, as much of the ritual practices are passed down orally and considered sacred by indigenous communities, making them difficult for researchers to access (Ritonga et al. 2023). Additionally, ethical issues and cultural sensitivities present significant challenges, as research interventions that are not carried out carefully can be seen as violations of traditional values. Furthermore, there is a shortage of researchers with interdisciplinary expertise, particularly in the combination of botany, anthropology, and ethnography, which results in a lack of studies that can bridge the scientific understanding with the spiritual or symbolic meaning of plant use in rituals (Fatur 2024).

In addition, limitations in funding, access to remote communities, and bureaucratic hurdles in obtaining research permits in indigenous areas also pose obstacles (Magsayo et al. 2024). The absence of a national platform specifically promoting research on ritual plants makes this area less exposed compared to other ethnobotanical subfields, such as medicinal or food plants. Other challenges include limited collaboration among institutions with relevant expertise and field data, as well as suboptimal publication in high-impact international journals due to language barriers and academic writing standards. To overcome these challenges, a collaborative and participatory approach involving local communities as research partners is needed, along with policy support and sustainable funding for research based on local wisdom (Aspan et al. 2023; Lestari et al. 2023).

The approach to studying the ethnobotany of ritual plants needs to shift from an ethnocultural perspective to an ethnoscientific one (Eldeen et al. 2016; Putra 2021). In general, existing studies on the ethnobotany of ritual plants have primarily examined ethnobotanical data from an ethnocultural standpoint, focusing on aspects such as philosophical values, usage, and plant parts utilized. These studies need to be expanded to include perspectives that are more universally accepted. For example, research could explore the phytochemistry of ritual plants, their potential as medicinal plants, their applications as natural fertilizers or pesticides, their role in ethnotourism, their market potential in ethnobotanical commerce, and conservation programs based on local wisdom. By broadening the scope in this manner, the study of the ethnobotany of ritual plants would no longer appear exclusive to specific ethnic or religious groups.

The gap in author collaboration

Indonesia ranks second in the world for biodiversity, following Brazil (Nugroho et al. 2023). This signifies that Indonesia should ideally be a global center for ethnobotanical research (Wilson et al. 2016). However, based on the authors' data regarding authorship, affiliations, countries, and sponsorships, it is evident that Indonesia has largely dominated ethnobotanical studies conducted within the country over the past decade. Collaboration among authors and between countries remains suboptimal, with research predominantly involving institutions within Indonesia. This dominance limits the global visibility and recognition of Indonesia's ethnobotanical research. Therefore, enhancing international collaboration is essential.

Ethnobotanical research collaboration within Indonesia continues to face significant challenges, primarily due to

disparities in infrastructure, resource access, and academic networking across local institutions (Purwaningrum 2016; Ghozi et al. 2023; Harsanto and Wahyuningrat 2024). Many universities and research centers in remote or underdeveloped areas lack sufficient laboratory facilities, digital tools, and skilled human resources, which hinders their ability to engage in collaborative research efforts. Additionally, inter-institutional collaboration is often constrained by bureaucratic procedures, uneven research funding distribution, and the absence of a cohesive national framework that facilitates researcher connectivity. These obstacles not only slow the advancement of ethnobotanical science but also lead to fragmented documentation and understanding of Indonesia's extensive traditional plant knowledge, knowledge that would benefit from integrated, interdisciplinary efforts across regions.

On the international level, collaborations between Indonesian researchers and global partners often encounter additional structural and ethical challenges (Prihatin 2016; White-Jones 2022; Abigail et al. 2023). Despite increasing global interest in Indonesia's biodiversity and indigenous knowledge systems, such collaborations can sometimes be imbalanced, with foreign institutions setting research priorities and leading project directions. Differences in research goals, institutional expectations, and funding structures may hinder equal partnership. Furthermore, language barriers, administrative hurdles in research permitting, and concerns surrounding intellectual property rights often complicate cross-border cooperation. To promote more equitable and impactful global collaboration, there is a pressing need for transparent agreements, co-ownership of research outcomes, and recognition of local expertise and cultural context. Strengthening these aspects will support the development of fair, respectful, and mutually beneficial scientific partnerships.

Improving collaboration can begin by fostering connections among researchers through conferences, discussion forums, and global academic networks (Osiek et al. 2009; Eberle et al. 2017). Funding opportunities should also be expanded beyond national sources to include international organizations such as UNESCO and collaborative research grants. The adoption of digital technology is crucial to facilitating efficient data exchange and communication via online platforms. Additionally, researcher exchange programs should be strengthened to deepen understanding of local knowledge across different regions. Furthermore, publishing in high-impact international journals and adopting a multidisciplinary approach integrating ethnobotany with phytochemistry, ecology, or economics can enhance the global relevance of ethnobotanical research.

The gaps in digital documentation

Keyword analysis using VOSviewer revealed no significant keywords related to internet-based digital documentation. In general, ethnobotanical data collection methods primarily involve interviews, field explorations, and literature reviews. The collected data is typically recorded in the form of tables, graphs, and photographs. However, these methods indicate that data is collected but not necessarily digitized in a centralized, easily accessible manner. Analog ethnobotanical data presents several limitations, such as storage constraints, difficulties in data access, susceptibility to damage or loss due to environmental factors, unattractive presentation, and inefficient and ineffective information analysis. If this trend continues, local wisdom related to ritual plants in Indonesia may be forgotten and lost. Therefore, digitalization must be implemented immediately. This can be achieved through: website development, mobile applications, social media utilization, and plant distribution mapping using Geographic Information System (GIS) or Google MyMaps (do Nascimento Fernandes de Souza and Hawkins 2020; Chitakunye et al. 2023).

One of the most pressing challenges in the digital documentation of ethnobotanical knowledge lies in the fact that much of the information regarding plant use among Indonesia's Indigenous communities remains oral, deeply embedded in tradition, language, and spiritual practice (Rinto et al. 2023). Field-based studies have shown that this knowledge is rapidly disappearing, driven by a decline in native language use and the shifting lifestyles of younger generations. The situation is further complicated by limited digital infrastructure in remote regions, where internet access, data storage tools, and digitally literate human resources are often scarce (Chitakunye et al. 2023). Ethical concerns also play a significant role, particularly regarding questions of data ownership, appropriate use, and the potential exploitation of knowledge that is sacred or collectively held (Maroyi 2020). Moreover, the absence of national standards for ethnobotanical documentation results in fragmented datasets that are often inaccessible, even to local researchers (Pirintsos et al. 2016).

Despite these challenges, promising solutions are emerging. One of the most effective approaches is the development of participatory digital documentation ecosystems, in which local communities are not merely subjects of study but active agents in recording and managing their own knowledge (Böhlen and Sujarwo 2020). This approach has been piloted in several community-based projects using low-tech tools such as offline mobile apps that enable voice and image-based recording in native languages. Equally important is the design of data storage systems that respect collective rights, using mechanisms like community-based access protocols or customary licensing models. Strengthening collaboration among researchers, technologists, government institutions, and Indigenous communities must be supported by national policies that prioritize the safeguarding of traditional knowledge. In this way, digitalization becomes not only a tool for preservation but also a means of empowerment and recognition for the rich, often hidden, knowledge systems rooted in Indonesia's forests, fields, and cultural rituals.

The role of the education system

Based on the most productive subject areas, it can be concluded that ethnobotanical conservation in Indonesia tends to adopt an ecological approach. This approach needs to be balanced with a socio-cultural approach, for example, through the education system. Education plays a crucial role in preserving local ethnobotanical wisdom by transferring

knowledge to younger generations (Arjaya et al. 2024; Pearnpitak et al. 2024; Marsandi et al. 2025). One of the key disciplines in this effort is biology education. Ethnobotanical themes and values can be integrated into the biology curriculum through two main approaches: intradisciplinary and interdisciplinary. The intradisciplinary approach can be implemented by integrating ethnobotanical themes and values into all biology courses, including genetics, morphology, taxonomy, and ecology. Meanwhile, the interdisciplinary approach involves incorporating ethnobotanical themes and values into various fields of study (Slikkerveer and Gellaerts 2024). Integration of ethnobotanical themes into various fields of study can be implemented through project-based assignments, such as the ethno-market project in economics, the ethno-tourism project in tourism studies, the ethno-policy project in law, and the ethno-cultural heritage project in cultural studies. Integrating ethnobotany into project-based learning provides an interdisciplinary learning experience, connecting students with traditional knowledge and cultural practices related to plant use (Salick 2014; Ramakrishna et al. 2020). This not only enhances learning engagement but also actively contributes to the preservation of local wisdom.

The integration of ethnobotany into primary and secondary school education holds tremendous potential for fostering ecological awareness, cultural understanding, and a strong sense of local identity among students from an early age (Rebello and De Meirelles 2022). However, to avoid falling into rigid, uniform teaching models, more human-centered, contextual, and original approaches are needed. One effective method is the "Ancestral Plant Traces" project, where students investigate the historical use of specific plants within their own families. For instance, they may interview grandparents about the plants used in the past for medicine, food, or rituals, and document these stories through personal narratives enriched with drawings or photographs. This technique not only integrates language and art skills, but also strengthens intergenerational bonds and cultivates pride in cultural heritage.

Data from community-based education initiatives in regions such as South Sulawesi and Central Kalimantan show that students involved in ethnobotany-based learning demonstrated up to a 35% increase in learning motivation, particularly in science and language subjects (Usman et al. 2024). Another underutilized yet impactful technique is the "Schoolyard Plant Safari," in which students explore their surroundings to identify local or wild plants, investigate their uses through local knowledge and interviews, and present their findings via school podcasts or mini-exhibitions. Rather than treating planting activities as mere assignments, this approach invites students to engage with the deeper meanings and socio-cultural connections of plants in their environment. These techniques are not only original and impactful but also position schools as dynamic spaces for preserving and revitalizing local ecological knowledge in meaningful and innovative ways (Azevedo et al. 2022; Serrano-Jiménez et al. 2025).

Based on the analysis results, several key conclusions can be drawn. First, the trend of scientific publications on ritual plant ethnobotany in Indonesia over the past decade has remained minimal and stagnant, with medicinal plant ethnobotany continuing to dominate the field. Second, the digitalization of ethnobotanical data remains underdeveloped, limiting access, preservation, and dissemination of knowledge.

To elevate the prominence of ritual plant studies, it is essential to foster stronger global collaboration, increase funding support, and implement sustainable conservation policies. Digitalization efforts should include the development of dedicated websites, mobile applications, social media engagement, and plant distribution mapping using Geographic Information System (GIS) tools or platforms such as Google MyMaps. Furthermore, the education system must contribute by reimagining the integration of ethnobotanical themes and values through both intradisciplinary and interdisciplinary approaches, ensuring the preservation and advancement of local knowledge in a modern context.

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Ethnoichthyological perspectives on anchovy utilization and classification in the Malacca Strait

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Abstract. *Ginting JH, Afrida A, Budarsa G, Jatmiko KA. 2025. Ethnoichthyological perspectives on anchovy utilization and classification in the Malacca Strait. Asian J Ethnobiol 8: 171-181.* This study investigates the ethnoichthyological dimensions of anchovy-based livelihoods in Tanjungbalai, a coastal community located along the eastern shoreline of North Sumatra, Indonesia. Anchovies (*Stolephorus* spp. and *Stolephorus waitei*), locally known as *ikan teri*, function not only as economic commodities but also as cultural agents deeply embedded within social, ecological, and gendered systems. Based on twelve months of ethnographic fieldwork using participant observation, interviews, and focus group discussions, this research explores how traditional ecological knowledge enables fishers to classify anchovy species using folk taxonomy, recognize ecological patterns, and adapt to seasonal environmental changes. The study documents a detailed folk taxonomy that distinguishes anchovy types based on morphology, behavior, habitat, and economic value. This local knowledge directly contributes to community-level biodiversity monitoring and supports ecosystem-based fisheries management. In addition, the findings reveal a gender-complementary division of labor, the operation of informal financial networks, and intergenerational modes of knowledge transmission that uphold socioeconomic resilience. By positioning TEK as a living system of field-based biodiversity observation and resource stewardship, the study offers critical insights for integrating local knowledge into participatory marine conservation strategies and sustainable fisheries governance in the Malacca Strait.

Keywords: Anchovy, biodiversity, ethnoichthyology, folk taxonomy, Malacca Strait, traditional ecological knowledge

INTRODUCTION

Indonesia, as the world's largest archipelagic state, possesses exceptional marine biodiversity, where small pelagic fisheries are vital for ecological balance and coastal livelihoods. Among these, anchovies (*Stolephorus* spp. and *Stolephorus waitei*), locally called *ikan teri*, play a prominent role in marine ecosystems and the cultural and economic lives of coastal communities. The *ikan teri* Medan label, widely recognized across Indonesia, signifies high-quality anchovy products that symbolize both regional identity and national culinary heritage (Ginting et al. 2024). Contrary to its name, these anchovies are predominantly harvested from Tanjungbalai and the Asahan Estuary, not Medan city.

Renowned for their soft texture and delicate flavor, *ikan teri* Medan are highly sought after in local and regional markets, including exports across Southeast Asia (Harper et al. 2012). This demand has shifted anchovies from subsistence food to a commercial commodity (Mulya et al. 2021). In Tanjungbalai, their commodification has shaped distinct labor hierarchies and gendered work divisions (Afrida and Ginting 2025), illustrating the importance of an ethnobiological lens that integrates biodiversity, traditional ecological knowledge, and local economies (Hutubessy et al. 2017). The Blue Revolution in the 1970s introduced modern fishing tools, significantly altering production systems (Putma et al. 2025). North Sumatra's coastal waters remain ecologically productive, hosting various small pelagic species including anchovies, especially in the nutrient-rich Malacca Strait (Warningsih et al. 2020). Annual landings reach 15,000-22,000 metric tons, largely caught by artisanal sondong fishers (North Sumatra Marine and Fisheries Agency 2023). Current harvesting is considered ecologically sustainable (FAO 2021), forming a baseline for understanding socio-ecological practices in the region (Setiabudi et al. 2018).

However, anchovies' cultural and epistemological values remain underexplored. While much research in Indonesia and Southeast Asia emphasizes resource management and policy (Adhuri et al. 2016; Pauly and Zeller 2016), it often overlooks embedded social relations, localized knowledge systems, and labor dynamics. Community resilience is closely tied to fisher capacity and adaptive livelihood strategies like occupation diversification and informal social networks.

This study focuses on the socio-ecological entanglements of anchovy fisheries in Tanjungbalai, viewing anchovies not merely as biological species but as central figures in shaping labor roles, gender dynamics, and knowledge transfer within households. Drawing on an ethnoichthyological approach, it explores how local ecological knowledge informs species recognition, fishing strategies, and responses to change (Alves et al. 2018; Djidohokpin et al. 2020). As a subfield of ethnozoology, ethnoichthyology links folk taxonomy and emic ecological

descriptors with biodiversity research (Hurn 2015; Oishi 2016; Hounkanrin et al. 2022; Basumatary et al. 2023).

Global studies demonstrate the value of this approach. Fishing communities use nuanced ecological knowledge to classify over 100 fish species (Silvano and Valbo-Jørgensen 2008; Turgo and Di Sciara 2021), assess seasonal changes and habitats (Rahman et al. 2022; Santos et al. 2023), and foster biodiversity monitoring and participatory governance (Kichwa de Rukullakta Community 2022; Montaña and Aranda 2022). Children in these communities also acquire LEK through daily interaction, reinforcing its transmission (Bottazzi and Boillat 2021). Scholars now increasingly recognize folk taxonomy knowledge as essential to inclusive marine conservation (Łuczaj and Svanberg 2020).

By situating anchovies (*Stolephorus* spp. and *S. waitei*) within both ecological and social frameworks, this study highlights their dual role as biological species and cultural actors. Drawing on twelve months of ethnographic fieldwork in Tanjungbalai's anchovy fishing communities along the Asahan Estuary, this research employs an ethnoichthyological approach to reveal how local ecological knowledge and folk taxonomy shape fishing practices, labor divisions, and intergenerational knowledge transmission. Ethnoichthyology allows for an integrated understanding that transcends the dichotomy between nature and culture: the biological traits and migratory patterns of anchovies inform local social organization, while folk taxonomy classifications, naming practices, and use strategies influence their conservation and management (Catelani et al. 2021; Gregory et al. 2024). In doing so, this study not only advances ethnoichthyological scholarship but also contributes to participatory, community-informed, and ecologically grounded marine resource governance in the Malacca Strait.

MATERIALS AND METHODS

Study area

This research was conducted in the coastal fishing communities of Tanjungbalai, situated along the eastern coastline of North Sumatra Province, Indonesia. As mentioned in Figure 1, the area encompasses the Asahan Estuary, which flows into the Malacca Strait, one of the world's richest fishing grounds for small pelagic species, including anchovies (*Stolephorus* spp. and *S. waitei*). Tanjungbalai has long been recognized as a major center for anchovy harvesting, processing, and export. Although popularly branded as the source of *ikan teri Medan*, the anchovies are predominantly harvested from this region rather than from the city of Medan itself. The community predominantly practices small-scale artisanal fisheries, where familial labor systems prevail and patron-client relationships with middlemen (*tengkulak*) shape the socioeconomic dynamics. The fishing fleet consists mainly of small vessels locally referred to as *sondong*, typically operated by a boat owner and a hired laborer (*anak buah kapal*, or ABK).

Research design

The study adopted an ethnographic design, following methodological traditions described by Spradley (2016) and refined by Hammersley and Atkinson (2019). Ethnography was selected because of its capacity to explore complex human-environment interactions, social practices, labor organization, and cultural meanings embedded in natural resource utilization. The research design incorporated participant observation, ethnographic interviews, and domain analysis based on Spradley's model. The broader inquiry was also informed by Creswell's (2018) qualitative research framework, emphasizing flexibility and reflexivity in the research process. An ethnobiological perspective was integrated throughout, focusing on the interplay between traditional ecological knowledge, biodiversity, and social organization.

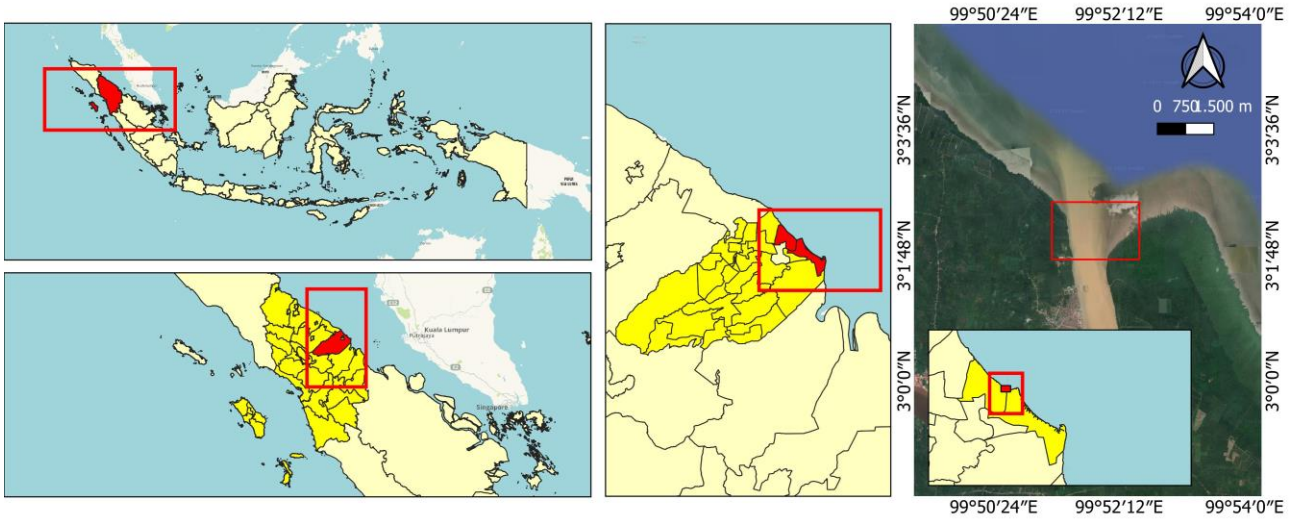

Figure 1. Map of study area showing the anchovy (*Stolephorus* spp.) fishing grounds in the coastal waters of North Sumatra, Indonesia

Data collection

Data were collected through year-long ethnographic fieldwork conducted between March 2023 and February 2024. Intensive participant observation enabled the researcher to engage directly with the daily routines of fishers, female sorters, and market traders, covering the entire production chain of anchovies (*Stolephorus* spp. and *S. waitei*), from offshore harvesting to onshore sorting and distribution. Participation in multiple fishing trips aboard *sondong* boats offered firsthand exposure to local fishing techniques and the ecological knowledge possessed by fishers.

Semi-structured and unstructured interviews were conducted with 26 key informants strategically selected to represent various nodes in the anchovy commodity chain. These included boat owners, captains (*tekong*), male crew members (ABK), female processors (wives of fishers and hired sorters), local middlemen (*tengkulak*), and market traders. The interviews followed Spradley's (2016) ethnographic strategies, employing both grand tour and mini-tour questions, and were supplemented with techniques from Creswell's (2018) qualitative interviewing model and Bernard's (2017) anthropological research methodology.

Three focus group discussions (FGDs) were held with fisher families to explore community perceptions surrounding the ecological and economic importance of anchovies. These discussions illuminated adaptive strategies in response to environmental pressures, fluctuating market conditions, and changes in social organization. Secondary data, including government fisheries production reports, legal and policy documents, and academic literature on North Sumatran fisheries, were also examined to contextualize the empirical findings. Visual ethnography was employed to document fishing practices, processing stages, and transactions in local markets, complementing oral narratives with photographic and video data. Fieldnotes were systematically recorded in line with the practices proposed by Emerson et al. (2011), combining thick description with analytic reflection to support iterative interpretation throughout the fieldwork.

A particular emphasis was placed on documenting local ecological knowledge (LEK), especially folk taxonomic systems related to anchovy species. Informants were asked to identify and differentiate anchovy types based on folk taxonomy names and associated morphological characteristics such as body size, coloration, scale texture, and flesh density. Ecological descriptors including habitat preference, behavior, and seasonal availability were also explored. Data were collected through semi-structured interviews, guided sorting sessions at landing sites, and observational activities during fish processing, allowing researchers to directly witness and validate local classification systems.

Sampling strategy

A purposive sampling strategy was applied to ensure that informants represented a wide range of roles within the anchovy fishery system. This approach was designed to capture the perspectives of individuals directly involved in production, processing, and trade. Snowball sampling was further employed to access individuals in critical yet less visible roles, such as those involved in informal debt arrangements between fishers and middlemen. The sampling process accounted for demographic diversity across age, gender, and occupational status, ensuring that the findings reflected the plurality of lived experiences within the community.

Folk taxonomy data analysis

Data were transcribed and analyzed thematically. Thematic coding focused on labor organization and gender roles, traditional ecological knowledge, patron-client economic relations, and community perceptions of environmental and market changes. Domain and taxonomic analysis methods from Spradley (2016) were applied to identify cultural categories and their interrelationships. The analytic process followed the ethnographic analysis strategies outlined by Spradley (2016). The analysis was also grounded in ethnobiological frameworks, which emphasize the interdependency of ecological knowledge and social organization. To trace the movement and transformation of anchovies as commodities, the research incorporated concept of the social life of things, from Appadurai (Evans 2018), situating the biological species within broader cultural and economic systems.

RESULTS AND DISCUSSION

In contemporary anthropological discourse, the scope of inquiry has broadened significantly to encompass the intricate relationships between humans and their environment. This expansion has led to the flourishing of fields such as Ethnozoology and Anthrozoology. Ethnozoology, as a distinct field, systematically investigates the interrelationships between human cultures and the animals within their ecosystems, exploring indigenous knowledge systems, cultural practices, and symbolic meanings associated with various fauna (Medeiros 2018). Anthrozoology, on the other hand, examines the complex and multifaceted interactions between humans and other animals, considering ethical, social, and ecological dimensions (Hurn 2015; Verheggen et al. 2017).

Building upon these foundations, our study introduces an ethnoichthyological perspective, which specifically delves into the profound and reciprocal relationship between human societies and fish populations. This approach acknowledges that ecological factors play a determining role in shaping how humans interact with specific fish species, subsequently influencing their livelihoods and cultural practices (Hounkanrin et al. 2022). This concept is well-explored in the emerging literature on ethnoichthyology across diverse contexts (Oishi 2016; Catelani et al. 2021; Basumatary et al. 2023; Gregory et al. 2024).

Folk taxonomy and local ecological knowledge of anchovies: An integrated ethnoichthyological perspective

Anchovies (*Stolephorus* spp. and *S. waitei*; see Figure 2) in the coastal waters of North Sumatra transcend their biological classification and function as cultural materials embedded within the socioeconomic and ecological fabric of Tanjungbalai's fishing communities. The eastern Sumatran coastline, which borders the Malacca Strait, possesses unique ecological features such as shallow waters ranging from one to five meters in depth, calm currents, and muddy to sandy seabeds. These conditions collectively create an ideal habitat for specific anchovy species. This environmental specificity significantly shapes the local ichthyofaunal profile. Unlike the larger and often more bitter-tasting anchovies harvested along the western coast of Sumatra, anchovies from the Malacca Strait are generally smaller and possess a milder, more desirable flavor. These qualities elevate their status as a high-value commodity and reinforce their essential role in local livelihoods. Anchovies also have nutritional and pharmacological value, containing bioactive peptides, omega-3 fatty acids, and antioxidants with health potential (Widowati et al. 2025).

From an anthropological perspective, this ecological embeddedness directly informs the complex human-fish relationship that is foundational to the coastal economy. The biological characteristics of anchovy species, including their size, palatability, preference for shallow estuarine habitats, and behavioral patterns such as nocturnal activity, influence the development of fishing technologies such as the *sondong* boat. These characteristics also determine the seasonality of harvesting activities and structure the organization of labor within fishing households. This interplay, where ecological features influence technological adaptation and social dynamics, lies at the heart of ethnoichthyological analysis.

Within the Tanjungbalai community, fisherfolk articulate a highly refined folk taxonomy that reflects deep empirical knowledge of local marine biodiversity (Table 1). Our research identified several locally prominent anchovy types, each distinguished by economic value as well as morphological and ecological characteristics. The most highly valued is *teri nasi*, characterized by its small, delicate body, shiny white coloration, and mild flavor. This type of anchovy commands a premium price, typically around IDR 65,000 per kilogram, and is considered the finest among local varieties. In contrast, *teri pekto*, referring to *S. waitei*, is larger, slightly duller in appearance, and of moderate quality, with a market price around IDR 45,000 per kilogram.

Beyond these primary anchovy types, fisherfolk recognize a diverse group of incidental catch referred to as *ikan sampah* or mixed fish. This category includes species such as *pakang* (*Anabas testudineus*), *cekong* (*Hemibagrus nemurus*), *kotip* (Leiognathidae), *gulama* (*Johnius* spp.), and *tamban* (*Spratelloides gracilis*). These species are generally less valued, sold at an average price of IDR 20,000 per kilogram. Fishers distinguish these species using a range of observable features such as body shape, size, skin texture, coloration, and behavioral traits, including how they swim or associate with anchovy schools. Although informal, this folk classification system is essential for sorting catch, setting market prices, and guiding fishing strategies.

Fisherfolk in Tanjungbalai distinguish anchovy species based on a systematic integration of morphological and behavioral cues. The primary comparison lies between *teri nasi* and *teri pekto*. *Teri nasi* is recognized by its small, fine-textured body, bright silver-white scales, and softer meat, making it preferred for sun-drying and short-distance trade. *Teri pekto*, by contrast, is larger, thicker-bodied, and less lustrous, with firmer flesh that requires longer drying time. Behaviorally, fishers report that *teri nasi* forms dense surface-level schools and is most abundant during nighttime spring tides, whereas *teri pekto* is more dispersed and appears predominantly during transitional monsoon periods near river mouths. These distinctions guide fishers in determining fishing location, net type, and sorting priorities. The practical classification based on morphology, ecology, and commercial value reflects a folk taxonomy that aligns with species-level differentiation, demonstrating the epistemic sophistication of local ecological knowledge.

Figure 2. Morphological differences between locally recognized anchovy types. A. *Stolephorus* spp., B. *Stolephorus waitei*

Table 1. Summary of folk taxonomy and local ecological knowledge of anchovy species in Tanjungbalai, North Sumatra, Indonesia

Local classification	Local name (Folk taxonomy)	Scientific name	Distinguishing features (According to fisherfolk)	Habitat/Behavior (Local knowledge)	Seasonal availability	Local use/Value
Ikan Teri	*Teri Nasi*	*Stolephorus* spp.	Small, shiny white body; soft, fine-textured flesh; highest market value	Active at night; caught in shallow estuarine waters with *pukat sondong*	Peak Jan-Mar & Oct-Dec	High-value drying & local delicacy
	Teri Pekto	*Stolephorus waitei*	Larger and duller than *teri nasi*; thicker body; moderate quality	Found near river mouths; common during seasonal transition periods	Transitional months	Moderate quality, processed longer
Ikan Sampah (Mixed Fish)	*Ikan Pakang*	*Anabas testudineus*	Thick body, rough scales; hardy freshwater fish	Occasionally caught near brackish areas during anchovy fishing	Irregular	Sold as low-value mixed fish
	Ikan Cekong	*Hemibagrus nemurus*	Flat head, dark body; strong smell; whiskered predator	Resides along riverbanks; bottom-dweller; rarely targeted	Irregular	Less preferred, sold cheap
	Ikan Kotip	Leiognathidae	Small, flat silvery body; fast swimmer; often mixed with anchovies	Bycatch from surface nets; swims close to anchovy schools	Irregular	Sold as low-value mixed fish
	Ikan Gulama	*Johnius* spp.	Heavy, yellowish body; firm texture; less favored	Bottom-dweller near muddy seabeds; caught unintentionally	Irregular	Sold as low-value mixed fish
	Ikan Tamban	*Spratelloides gracilis*	Slender silver body; smooth texture; suitable for smoking or drying	Appears seasonally; netted in coastal shallows alongside anchovies	Irregular	Sold as low-value mixed fish

The seasonal abundance of anchovy species varies considerably and is closely linked to local climatic and oceanographic patterns. Field observations indicate that harvests peak between January and March, and again from October to December, with daily catches ranging from 90 to 130 kg. During off-peak periods, particularly between April and August, catches drop significantly, sometimes yielding as little as 10 to 15 kg per day. These fluctuations have a direct impact on household income and economic security. Drawing on traditional ecological knowledge passed down through generations, local fishers often prefer to conduct fishing operations at night, based on their understanding that anchovies are more active and easier to capture in darkness. While this study does not specifically address reproductive biology, data from the North Sumatra Marine and Fisheries Agency (2023) indicate that provincial anchovy landings average between 15,000 and 22,000 metric tons annually.

According to the Food and Agriculture Organization (FAO 2021), anchovy fisheries in the Malacca Strait remain ecologically sustainable, with mortality levels indicating normal exploitation intensity. This environmental stability supports a dynamic local economy, where approximately 80 percent of households in areas such as Teluk Nibung sub-district participate in the anchovy value chain. These households engage in activities ranging from harvesting and sorting to drying and marketing. The dominant fishing fleet consists of small-scale *sondong* boats, typically operated by a boat owner and one or more crew members (ABK). These boats are carefully constructed from local timbers such as *kayu malas*, *kayu meranti*, *kayu moli*, *kayu haloban*, and *kayu lunas*. They are powered by single-cylinder engines and cruise at speeds of five to seven knots, making them ideal for shallow-water operations targeting anchovy-rich habitats. Most of these boats are under 10 gross tonnage, a classification that exempts them from the requirement of holding formal fishing licenses under current Indonesian maritime regulations. This regulatory status shapes not only local fishing practices but also how communities interface with national fisheries management systems (Stori et al. 2019; Sari et al. 2022).

The integration of ecological adaptation, regulatory frameworks, and artisanal fishing practices exemplifies the core principles of ethnoichthyology. The technical design of *sondong* vessels and the fishers' deep knowledge of lunar cycles, tides, spawning zones, and species behavior form an adaptive system rooted in cultural resilience and ecological insight. As seen in comparable studies, traditional ecological knowledge contributes significantly to biodiversity research. It helps identify species (Catelani et al. 2021), map dynamic fishing grounds, and monitor population health in marine ecosystems (Gregory et al. 2024). In Tanjungbalai, fisherfolk distinguish species not solely by commercial value, but also through detailed understanding of anatomical, behavioral, and ecological traits. These forms of knowledge, developed through sustained interaction with local waterscapes, act as dynamic, field-based biodiversity observations.

The anchovy fishery of Tanjungbalai thus constitutes an active interface between ecological knowledge and social organization. The folk taxonomy practiced by fishers, when documented and engaged in dialogue with scientific frameworks, holds potential to enhance formal fisheries management and biodiversity conservation. Integrating such knowledge into policy opens pathways for participatory, adaptive, and culturally grounded marine governance. Rather than anecdotal, traditional ecological knowledge represents a living, cumulative system of observation and interpretation that remains essential to both the resilience of coastal communities and the sustainability of the marine environment (Hounkanrin et al. 2022; Chambon et al. 2024).

Economic dynamics and livelihood outcomes

Anchovies (*Stolephorus* spp.) are not only economically important for fishers, but also offer emerging value as marine nutraceuticals, due to their rich content of bioavailable micronutrients and bioactive compounds (Widowati et al. 2025). The anchovy fishery in Tanjungbalai, while a vital economic driver, operates within complex financial dynamics characterized by significant fluctuations in income and a challenging cost structure for fishing households. Our ethnographic findings, supplemented by concrete quantitative indicators from fieldwork, illustrate the economic realities faced by various actors within this value chain.

The daily wages for crew members (*ABK*) and captains (*tekong*) are fixed at IDR 100,000 per person per day, regardless of the catch volume. This model provides a degree of income stability for laborers, distributing economic risks more evenly compared to profit-sharing systems common elsewhere. Female sorters, crucial to post-harvest processing, are compensated at a rate of IDR 30,000 per boat for their sorting efforts. However, their daily earnings can increase significantly as many sorters handle fish from multiple boats, potentially reaching IDR 100,000 per day if they sort for several vessels. Monthly income for female sorters, for instance, can range from IDR 500,000 during periods of abundant catches to a more modest IDR 200,000-300,000 during lean seasons. This income is often used to supplement household needs, purchase children's snacks, or, in some cases, for personal expenditures or participation in informal savings groups like *arisan*.

Boat owners, positioned at the apex of the labor hierarchy, bear the primary financial risks and expenses. Their gross income from a single fishing trip (typically lasting 3-4 days) can range from IDR 3,000,000 to IDR 7,000,000. However, this is a gross figure, subject to substantial operational costs and profit-sharing arrangements. Fishing operations, especially for sondong boats, involve significant initial outlays. A new sondong boat can cost up to IDR 100.000.000, while a used one ranges from IDR 60-80 million. Daily operational expenses for a 3-5 day trip are considerable, estimated between IDR 2,000,000 to IDR 4,000,000. This includes fuel (solar), which costs IDR 300,000 per jerrycan (15 liters), with 7 jerrycans needed for a 5-day trip; gas (typically 10 units of

3 kg gas cylinders for a trip); salt (IDR 200,000 per sack, with 3-4 sacks needed); and food supplies for the crew (Table 2). Additionally, there are costs for maintaining the boat, repairing engines, and purchasing fishing gear. A detailed calculation from our fieldwork illustrates the financial tightrope walked by boat owners. For a 3-day trip yielding 50 kg of anchovies, with anchovy prices from *tengkulak* at IDR 65,000/kg (Table 3).

This net profit of IDR 900,000 for a 3-day trip, while seemingly modest, highlights the constrained profit margins for boat owners, especially when considering initial investments and the unpredictable nature of catches. This situation often forces boat owners to rely on loans from *tengkulak* (middlemen) (see Figure 3), perpetuating a cycle of indebtedness. This economic vulnerability is further exacerbated during periods of low catch, leading to mounting debts that can hinder long-term economic mobility and bargaining power within the patron-client system.

The market price of anchovies exhibits considerable volatility. While tengkulak might purchase anchovies from fishers at around IDR 65,000/kg (even during times of scarcity), the same product can be retailed at IDR 110,000/kg in the market, illustrating the significant profit margins captured by middlemen in the distribution chain. This price disparity, combined with declining catches, severely constrains the income of fishers and processors, compelling them to adapt through informal financial networks and diversified household incomes.

Patron-client relations, environmental uncertainty, and adaptive strategies

Patron-client relationships in the anchovy fisheries of Tanjungbalai create both economic opportunities and power asymmetries. Boat owners and *tengkulak* not only provide employment and credit but also control market access and pricing structures. Crew members and female workers often remain economically dependent on patrons, particularly when credit arrangements evolve into long-term debt obligations (Husni et al. 2022).

While these relationships offer stability in uncertain economic contexts, they also perpetuate social stratification and dependency. As Crona and Bodin (2010) observed, such power asymmetries can hinder governance transformability and labor mobility. Environmental changes compound these economic vulnerabilities. Fishers reported declining anchovy catches over recent years, attributing reductions to sedimentation, coastal development, increased competition, and unpredictable weather patterns—observations consistent with regional scientific literature (Winarno and Salsabila 2024).

These environmental uncertainties have prompted adaptive strategies such as modifying fishing gear, shifting fishing grounds, and diversifying household incomes through small-scale aquaculture or trade. Local ecological knowledge remains central to these adaptations. Fishers employ detailed understandings of tides, lunar cycles, and fish behavior, reflecting a resilience-oriented approach to environmental change (Muawanah et al. 2018; Ullah et al. 2023).

However, this knowledge system faces erosion as younger generations seek alternative livelihoods and as technological shifts outpace traditional learning. Framing this within Appadurai's concept of the social life of things (Evans 2018), anchovies are not passive resources but agents that mediate labor relations, gender roles, and economic structures. As they move through production and distribution networks, anchovies accumulate social meanings and economic values, reinforcing their role as both ecological and cultural keystones.

Gendered labor and economic rights in anchovy production

The anchovy fishery in Tanjungbalai represents a socioeconomic system where gender roles are clearly defined yet complementary. Men dominate the production side, particularly fishing at sea using *sondong* boats, while women undertake post-harvest processing tasks, mainly sorting and grading the catch. This division of labor is not merely traditional but forms a resilient economic model where both genders contribute uniquely to household and community livelihoods.

Table 3. Fishing trip revenue and profit calculation

Description	Calculation	Amount (IDR)
Total revenue	50 kg × 65,000/kg	3,250,000
Total expenses	Fuel, gas, salt, food, wages (ABK, tekong, sorter, dryer, *tukang becak*)	2,350,000
Net profit (boat owner)	IDR 3,250,000 - IDR 2,350,000	900,000

Note: 1 USD = ~ 16,000 IDR

Table 2. Breakdown of fishing trip operational costs

Item	Quantity (Estimate per 3-5 day trip)	Unit cost (IDR)	Total cost (IDR) (Estimate)
Solar fuel	7 jerrycans (15 liters/jerrycan)	300,000/jerrycan	2,100,000
LPG gas 3 kg	10 cylinders	Variable	250,000
Salt	3-4 sacks	200,000/sack	600,000-800,000
Crew food needs	Optional	Variable	200,000
ABK wages	3 days (per person)	100,000/day	300,000 (per *ABK*)
Captain (*tekong*) wages	3 days	100,000/day	300,000
Sorter wages	1 person (per boat)	30,000/boat	30,000
Dryer/spreader wages	Based on kg	800-1,500/kg	60,000 (for 17 kg)
Becak driver wages	1 boat	10,000/boat	10,000

Onboard *sondong* vessels, only men serve as captains and crew due to the physical demands and sanitary challenges of multi-day fishing trips (Figure 5). Once ashore, women sort the catch into various commercial grades. Their work determines the final market value of the anchovies, particularly prized varieties like *teri seppo* and *teri kase*, while less valuable bycatch such as *kotip* fish is either sold cheaply or retained for household consumption. Despite the skill involved, female sorters typically earn low daily wages, often IDR 30,000.00 per boat, with no formal contracts or social security. This reflects a broader trend in small-scale fisheries across Southeast Asia, where women play indispensable roles yet face persistent economic marginalization (Teniwut et al. 2022; Nurhayati et al. 2023). Women's labor is often seen as an extension of domestic responsibilities rather than professional work warranting equitable remuneration (Nurhayati et al. 2023).

In Tanjungbalai, even though women's sorting work enhances the efficiency and profitability of fishing operations, their contributions remain undervalued in both economic and policy frameworks (Figure 4). However, recent studies emphasize that these gendered divisions are not static. They often evolve into systems of gender complementarity where women exercise considerable agency in managing household finances and diversifying income sources (Gustavsson and Riley 2018). Financial autonomy among women in Tanjungbalai is further reinforced by their participation in rotating savings groups (*arisan*) and informal credit systems (Spyrou et al. 2021). Such mechanisms provide liquidity for daily needs, children's education, and even fishing operations, including fuel purchases and gear repairs. This mirrors findings from similar fisheries in Malaysia and North Borneo, where women leverage social capital and informal financial networks to navigate labor inequities and economic uncertainty.

Knowledge transmission, cultural continuity, and the future of anchovy fisheries in Tanjungbalai

In the anchovy fisheries of Tanjungbalai, knowledge transmission is not merely a cultural practice but a critical component sustaining the ecological and economic viability of the sector. Traditional ecological knowledge encompasses a wealth of local expertise, from precise fishing techniques (e.g., operating sondong boats and interpreting subtle signs of the sea) to intricate seasonal patterns and efficient post-harvest processing skills. This knowledge is primarily passed down across generations through embedded social learning processes rather than formal instruction. Fathers often impart fishing wisdom and practical skills to sons during shared fishing trips (Ginting and Anwar 2024), while mothers diligently transmit sorting and grading expertise to daughters and younger female relatives during daily post-harvest activities. This hands-on, experiential learning is crucial for the preservation of local expertise.

However, this vital transmission model confronts significant challenges, particularly from external socioeconomic pressures and internal dynamics within the community. Younger generations are increasingly expressing disinterest in pursuing traditional fishing livelihoods. This disinclination stems from a perception of low economic returns, coupled with the allure of more stable, less arduous urban employment opportunities. This trend represents a substantial threat to the cultural continuity of TEK, as fewer individuals are available or willing to inherit and perpetuate these specialized skills and knowledge systems.

Figure 4. Fisherman's wife works as an anchovy sorter

Figure 5. *Sondong*, anchovy fishing vessel in Tanjungbalai

Women play a particularly pivotal role in both the economic and knowledge spheres of this fishery. Female fish sorters not only directly determine the market value of the catch through their meticulous work but also serve as key knowledge bearers and transmitters. Through daily interactions at the dock, these women actively share information about fluctuating market trends and innovative processing techniques. Crucially, information concerning changing ecological conditions (e.g., shifts in fish behavior or habitat) is primarily received by women from the male fishers who work at sea and observe these changes firsthand. This collected information is then summarized and analyzed by women from various sources, significantly increasing their role in the communication and dissemination of knowledge within the community. This informal, yet highly effective, social learning environment among women is essential for maintaining the socio-ecological resilience of fisheries, mirroring findings from other regions where women are recognized as central to adaptive capacity and knowledge persistence.

More critically, this knowledge base empowers women to engage in co-decision-making within their families regarding adaptive strategies. For instance, when women observe a consistent decline in the quantity or quality of anchovies brought ashore, and combine this with information from fishers about changes in fish behavior or habitat, they often initiate discussions with their husbands or male relatives about modifying fishing locations or techniques. They might suggest exploring alternative fishing grounds based on their market observations, or propose diversifying household income by expanding the production of processed anchovy products (e.g., *kerupuk ikan*) when raw catches are low. This active participation extends to financial decisions, where women, leveraging their roles in *arisan* and informal credit systems, collaboratively decide on investments for fishing gear repair or even to manage household expenditures during lean fishing seasons. Such collaborative decisions underscore the shared responsibility and mutual influence of men and women in ensuring the livelihood's sustainability.

Nevertheless, the informal nature of TEK makes it inherently vulnerable to erosion, especially as the fishing workforce ages and fewer young people enter the sector. Formal documentation efforts are scarce, and existing national fisheries policies often fail to adequately recognize or integrate TEK into official management frameworks (Muawanah et al. 2018; Purwanti et al. 2021). Without systematic efforts to record, validate, and disseminate this invaluable local knowledge, a significant portion of it risks being permanently lost, diminishing the community's adaptive capacity.

Despite these challenges, social learning environments, such as the communal sorting areas, continue to facilitate the transmission of innovative adaptive strategies. For instance, women have collectively developed and refined informal credit systems and rotational savings groups (*arisan*) to manage income volatility and buffer against economic shocks (Spyrou et al. 2021). Such practices not only provide immediate financial stability but also foster intergenerational learning about resource management, financial literacy, and collective resilience. Efforts to bridge traditional knowledge with modern science are gaining traction. Collaborative initiatives involving fishers, researchers, and policymakers have demonstrated that integrating TEK with scientific data can significantly enhance fisheries management outcomes. In Raja Ampat, for example, the inclusion of fishers' ecological knowledge in anchovy management plans led to improved compliance and conservation results (Sari et al. 2022), serving as a replicable model for Tanjungbalai.

Women's empowerment is central to effectively integrating TEK and fostering long-term resilience. Empowerment programs that provide technical training, financial literacy, and leadership opportunities have shown immense promise in other Indonesian fisheries (Alami and Raharjo 2017; Sornkliang et al. 2018). By enhancing women's roles not just as workers but as active decision-makers in resource management and economic planning, these initiatives strengthen both knowledge transmission pathways and overall community resilience. Furthermore, integrating local fisheries knowledge into school curricula can encourage youth engagement and foster pride in traditional livelihoods (Spyrou et al. 2021), potentially reversing the trend of disinterest. Innovative digital documentation methods, such as videos and social media platforms, also offer powerful avenues to preserve and share TEK with younger, tech-savvy generations (Schiemer et al. 2024). In other coastal areas, similar integration of local ecological knowledge into tourism practices has shown that fishermen can create unique tourism experiences that attract environmentally conscious tourists and contribute to the sustainability of the tourism industry by leveraging their ecological expertise and cultural heritage (Zamzami 2024).

This study highlights the complex socio-ecological relationships surrounding anchovy (*Stolephorus* spp.) fisheries in Tanjungbalai, emphasizing how local ecological knowledge, labor hierarchies, and market dynamics converge to shape coastal livelihoods. Anchovies are not only a vital economic commodity but also a cultural and ecological keystone that reflects the adaptive strategies of fishing communities in navigating fluctuating environmental conditions and capitalist market demands. By documenting folk taxonomy and traditional ecological practices, this research demonstrates that local knowledge systems are indispensable for understanding species diversity and maintaining sustainable marine resource management. In this light, collaborative governance models that integrate community-based knowledge with modern fisheries policies could enhance both biodiversity conservation and socioeconomic resilience in the Malacca Strait.

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Ethnobotanical heritage of Ban Nongtae Community Forest, Ban Dan District, Buri Ram Province, Thailand

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Abstract. *Saensouk P, Saensouk S, Boonma T, Rakarcha S, Setyawan AD, Chanthavongsa K, Jitpromma T. 2025. Ethnobotanical heritage of Ban Nongtae Community Forest, Ban Dan District, Buri Ram Province, Thailand. Asian J Ethnobiol 8: 182-191.* This study explores plant diversity and ethnobotanical uses in the Ban Nongtae Community Forest, Buri Ram Province, Thailand. Field surveys and interviews were conducted with 30 local informants to document species and their uses. The data were analyzed using descriptive statistics to summarize use categories, species frequency, and life forms, providing insight into community reliance and conservation priorities. A total of 33 plant species from 20 families were identified, with Apocynaceae and Fabaceae each of 4 species (12.12%) being the most utilized. The dominant life forms were herbs and shrubs, indicating a vegetation structure sensitive to disturbance. The local community depends on these plants for daily needs, i.e. 18 species are used for medicine, 12 species for food, and others for fuel, fodder, ornamentals, and rituals. Notable species, include *Calotropis gigantea* (L.) W.T.Aiton and *Urceola polymorpha* (Pierre) D.J.Middleton & Livsh. have high use values of 0.40 and 0.37, respectively. Most species, 29 out of 33 species (87.8%) are native and play key roles in maintaining ecosystem resilience. However, unsustainable practices, such as harvesting heartwood, pose risks to plant populations. Conservation efforts should prioritize native species with high use values, promote sustainable harvesting, and integrate traditional knowledge to support long-term biodiversity and ecosystem stability.

Keywords: Buri Ram Province, community forest, ethnobotany, medicinal plants, Thailand, traditional knowledge, use value, utilization

INTRODUCTION

Ethnobotany examines how people use plants in daily life, offering insights into the interactions between cultural practices and natural environments (Salako et al. 2018; Balick and Cox 2020). Local communities often possess rich traditional plant knowledge, accumulated over generations and used for medicinal, nutritional, cultural, and ornamental purposes (El Mekkaoui et al. 2024; Saensouk et al. 2025a, b). In Thailand, especially in rural areas, this knowledge remains closely tied to livelihoods and local customs (Khunweechuay et al. 2022). However, modernization, environmental change, and generational shifts increasingly threaten its survival (Wali et al. 2017; Arjona-García et al. 2021; Dean 2024). As such, documenting ethnobotanical knowledge is essential not only for cultural preservation but also for biodiversity conservation and sustainable development. Ban Nongtae Community Forest in Ban Dan District, Buri Ram Province, Thailand, provides a unique case where local plant use remains integral to everyday life. The forest supports a variety of species used for food, medicine, rituals, construction, and other cultural practices (Mavhura and Mushure 2019). For instance, *Calotropis gigantea* (L.) W.T.Aiton (giant milkweed or crown flower) is used in spiritual ceremonies such as Bai Sri offering and the Bai Sri Su Khwan ritual. The community is ethnically diverse—comprising Thai-Korat, Lao Isan, Thai-Khmer, and Thai-Suay people—each contributing to a collective pool of plant knowledge shaped by long-term interaction with the forest ecosystem. Their practices reflect sustainable and low-impact resource use, often informed by traditional ecological knowledge.

Despite its cultural and ecological importance, this body of knowledge is increasingly at risk. Deforestation, the expansion of modern agriculture, and changes in lifestyle are contributing to the erosion of traditional practices (de Santana et al. 2024). If not documented in time, valuable knowledge may be lost irreversibly (Boonma et al. 2023, 2024). Ethnobotanical research plays a critical role in identifying culturally important species and understanding their contribution to ecosystem services and community well-being (Chekole 2017; Gitima et al. 2025). Furthermore, localized studies can inform conservation efforts that bridge traditional knowledge and scientific approaches (Barmashova and Lazutkina 2020).

Although some national and regional ethnobotanical surveys have been conducted in Thailand, detailed, site-specific studies remain scarce in the northeastern region, particularly in culturally diverse areas like Ban Nongtae. According to Joa et al. (2018) and Saensouk et al. (2025a), localized inventories are vital for understanding how ethnic diversity influences plant use and conservation behavior. Given the multi-ethnic composition of Ban Nongtae and its continued dependence on forest resources, a focused ethnobotanical investigation is both timely and necessary.

Therefore, this study aims to (i) document the plant species used by the Ban Nongtae Community; (ii) examine their uses across categories such as food, medicine, rituals, and others; and (iii) assess their cultural significance to support biodiversity conservation and the preservation of traditional knowledge. This research provides essential baseline data to inform future conservation planning and underscores the importance of integrating local ecological knowledge into sustainable resource management strategies.

MATERIALS AND METHODS

Study area

Ban Nongtae Community Forest is located in Ban Nong Tae, Non Khwang Sub-district, Ban Dan District, Buri Ram Province, Thailand (15°11′33″N, 103°9′16″E), covering an area of approximately 3.2 ha (Figure 1). This forest is dominated by native hardwood species e.g., *Ridsdalea wittii* (Craib) J.T.Pereira and *Ellipanthus tomentosus* Kurz which adapted to the region's seasonal tropical climate. The community collectively conserves and manages the forest, which serves as a vital source of natural resources supporting their livelihoods. These include food, medicinal herbs, fuelwood, animal fodder, and plants used in various cultural and ritual practices.

Procedures

A plant survey was carried out in Ban Nongtae Community Forest from December 2024 to February 2025. The study involved interviews with 2 local experts, 2 traditional healers, 8 elders, and 18 villagers, with total 30 participants providing valuable insights. These interviews covered local plant names, utilization, their medicinal properties (if used as medicinal plants), preparation methods, and the specific plant parts used. The identified plant species were documented by recording their local names, taking photographs, and collecting samples for herbarium preparation. The plant samples were preserved at the Vascular Plant Herbarium, Mahasarakham University (VMSU).

The morphological features of the collected voucher samples were examined under a stereoscopic microscope (Stemi 2000-C, Zeiss, Oberkochen, Germany). Measurements were taken using a ruler and vernier caliper to ensure precise documentation. Species identification was confirmed by comparing the specimens with descriptions and reference materials available through Plants of the World Online (POWO 2025) (https://powo.science.kew.org) and the International Plant Names Index (IPNI) (https://www.ipni.org). We specifically utilized the "First published in" information provided under each scientific name to access original protologue documents for verification. A thorough review of key taxonomic literature and research databases, including Scopus (https://www.scopus.com), Web of Science (https://www.webofscience.com), Google Scholar (https://scholar.google.com), and ResearchGate (https://www.researchgate.net), was also performed. Additionally, comparisons were made with digital images from Kew's Herbarium and Plants of the World Online, as well as with specimens housed at major Thai herbaria, such as BK (Bangkok Herbarium, Department of National Parks, Wildlife and Plant Conservation), BKF (Forest Herbarium, Bangkok), KKU (Khon Kaen University Herbarium), QBG (Queen Sirikit Botanic Garden Herbarium), and VMSU (Vascular Plant Herbarium, Mahasarakham University) to ensure accurate identification.

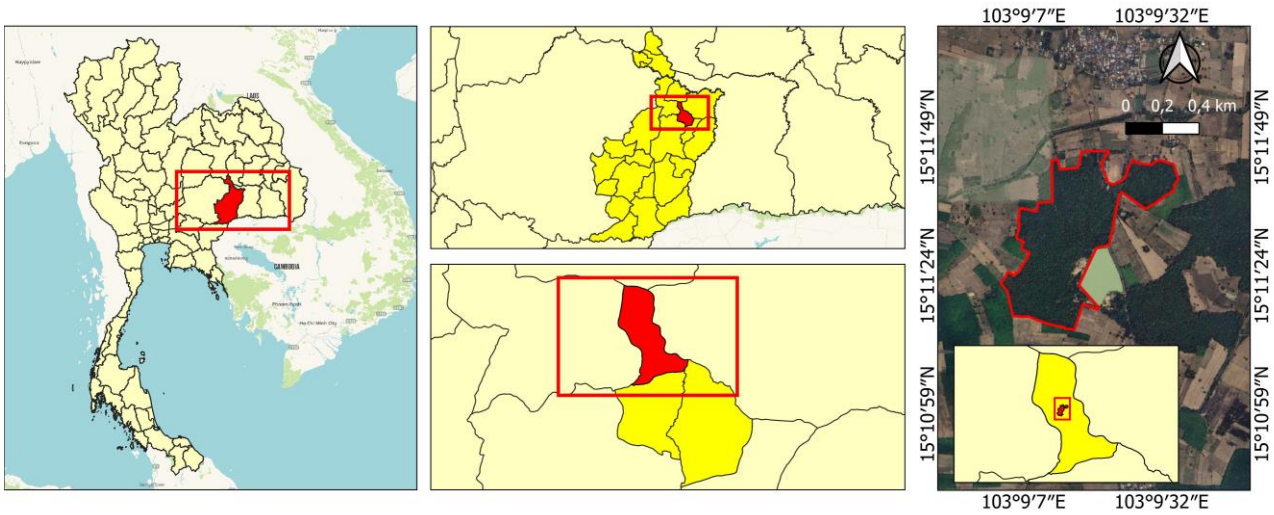

Figure 1. Ban Nongtae Community Forest in Ban Nong Tae, Non Khwang Sub-district, Ban Dan District, Buri Ram Province, Thailand

Ethical considerations: Verbal prior informed consent was obtained from all participants before interviews were conducted. The study followed local ethical standards and was conducted with the approval and participation of community leaders.

Data analysis

Several indices are employed to evaluate the significance and reliability of plant use within communities, such as Use Value (UV) index, Informant Consensus Factor (Fic), and Fidelity Level (FL). These indices are essential tools in identifying key species and plant parts for further research, conservation, and potential application in healthcare and sustainable development.

Use Value (UV) index

The Use Value (UV) index reflects the significance of a plant species within a particular region (Phillips et al. 1994). It is calculated using the following formula:

$$UV = \frac{\sum_i UV_{is}}{n_s}$$

Where: UV index represents the overall use value of the species, UV_{is} is the use value of the species by each informant, and n_s refers to the total number of informants who were interviewed for that species.

Informant consensus factor (F_{ic})

The Informant Consensus Factor (F_{ic}) was used to assess the variability in medicinal plant usage and was computed using the following formula (Heinrich et al. 1998):

$$F_{ic} = \frac{n_{ur} - n_t}{n_{ur} - 1}$$

Where: n_{ur} represents the total number of use reports within a given category, and n_t refers to the number of plant species utilized in that category. The F_{ic} value indicates the degree of consensus among informants about the medicinal plant usage, with higher values showing stronger agreement on the use of specific plants for particular therapeutic purposes.

Fidelity Level (FL)

The Fidelity Level (FL) quantifies the percentage of informants who linked a particular plant species to a specific ailment within the study area. It is calculated using the formula described by Friedman et al. (1986) as follows:

$$FL = \frac{I_p}{I_u} \times 100$$

Where: I_p refers to the number of informants who identified the plant as a remedy for a particular disease, and I_u is the total number of informants who acknowledged the plant's medicinal use for any health issue.

RESULTS AND DISCUSSION

Diversity of plants

A total of 33 plant species, belonging to 20 families, were recorded in Ban Nongtae Community Forest, Ban Nongtae, Ban Dan District, Buri Ram Province, Thailand (Table 1; Figure 2). The most represented families were Apocynaceae and Fabaceae, each with 4 species, followed by Rubiaceae with 3 species. Other notable families included Cucurbitaceae, Euphorbiaceae, Malvaceae, Ochnaceae, and Rutaceae, each with 2 species, contributing significantly to the forest's plant diversity. Families with a single species each included Annonaceae, Boraginaceae, Commelinaceae, Connaraceae, Dipterocarpaceae, Erythroxylaceae, Lecythidaceae, Melastomataceae, Rhamnaceae, Salicaceae, Stemonaceae, and Verbenaceae. Of the recorded species, 29 are native species, accounting for 87.88%, while 4 are introduced species, making up 12.12%.

The distribution of life forms among the plants in Ban Nongtae community forest is as follows: shrubs account for the highest percentage, with 12 species (36.36%), followed by trees with 11 species (33.33%). Climbers make up 6 species (18.18%), while herbs comprise 4 species (12.12%) (Table 1).

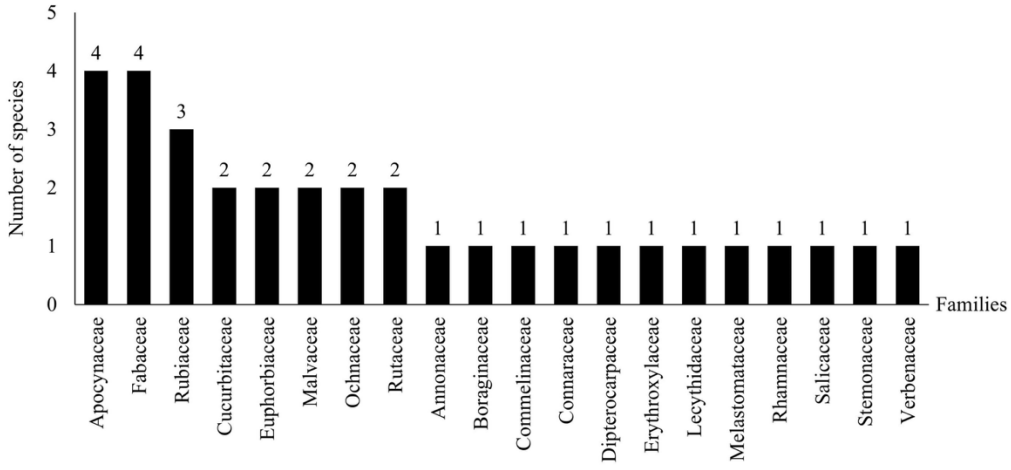

Figure 2. Plant diversity in Ban Nongtae Community Forest, Ban Nongtae, Ban Dan District, Buri Ram Province, Thailand

Table 1. Diversity of plants in Ban Nongtae Community Forest, along with their local name, habits, distribution, utilization, used parts, and specimen voucher

Family	Scientific name	Local name	Habits	Distribution status in Thailand	Utilization	Used parts	UV index	Voucher no.
Annonaceae	*Polyalthia evecta* (Pierre) Finet & Gagnep.	Mak Tong Laeng	Shrub	Native	FD	FT	0.33	TJ351
Apocynaceae	*Calotropis gigantea* (L.) W.T.Aiton	Rak	Shrub	Native	MD, RC	IR, RT	0.40	TJ352
Apocynaceae	*Oxystelma esculentum* (L.fil.) Sm.	Chamuk Pla Lot	Climber	Native	FD	IR, LV	0.20	TJ353
Apocynaceae	*Urceola polymorpha* (Pierre) D.J.Middleton & Livsh.	Som Lom	Climber	Native	FD	FT	0.37	TJ354
Apocynaceae	*Holarrhena pubescens* (Buch.-Ham.) Wall. ex G.Don	Mok Yai	Tree	Native	MD	BA, IR	0.23	TJ355
Boraginaceae	*Heliotropium indicum* L.	Ya Nguangchang	Herb	Introduced	MD	IR, SM	0.20	TJ356
Commelinaceae	*Commelina benghalensis* L.	Phak Plap	Herb	Native	AF	WP	0.13	TJ357
Connaraceae	*Ellipanthus tomentosus* Kurz	Ta Nok Kot	Tree	Native	MD	HW, RT, SM	0.10	TJ358
Cucurbitaceae	*Coccinia grandis* (L.) Voigt	Tamlueng	Climber	Native	FD	LV	0.23	TJ359
Cucurbitaceae	*Solena amplexicaulis* (Lam.) Gandhi	Bung Len	Climber	Native	MD	LV	0.13	TJ360
Dipterocarpaceae	*Dipterocarpus intricatus* Dyer	Sa Baeng	Tree	Native	AP, FL, RC	FT, SM	0.30	TJ361
Erythroxylaceae	*Erythroxylum cambodianum* Pierre	Ma Hok Ton	Shrub	Native	MD	RT	0.20	TJ362
Euphorbiaceae	*Suregada multiflora* (A.Juss.) Baill.	Mot	Tree	Native	MD	BA, RT	0.17	TJ363
Euphorbiaceae	*Trigonostemon reidioides* (Kurz) Craib	Lot Thanong	Shrub	Native	MD	RT	0.13	TJ364
Fabaceae	*Bauhinia saccocalyx* Pierre	Som Siao	Shrub	Native	FD, ON	LV, WP	0.27	TJ365
Fabaceae	*Leucaena leucocephala* (Lam.) de Wit	Krathin	Shrub	Introduced	AF, FL	LV, SM	0.30	TJ366
Fabaceae	*Senna garrettiana* (Craib) H.S.Irwin & Barneby	Khilek San	Tree	Native	FD, FL, ON	LV, SW, WP	0.27	TJ367
Fabaceae	*Senna occidentalis* (L.) Link	Len Khet	Shrub	Introduced	MD	LV, RT	0.23	TJ368
Lecythidaceae	*Careya arborea* Roxb.	Kra Don	Tree	Native	FD	LV	0.20	TJ369
Malvaceae	*Bombax anceps* Pierre	Ngio Pa	Tree	Native	AP, FL	FT, SM	0.17	TJ370
Malvaceae	*Helicteres hirsuta* Lour.	Khithao	Shrub	Native	MD	FT, HW	0.07	TJ371
Melastomataceae	*Memecylon scutellatum* (Lour.) Hook. & Arn.	Mueat Ae	Shrub	Native	MD	RT, SM	0.10	TJ372
Ochnaceae	*Campylospermum serratum* (Gaertn.) Bittrich & M.C.E.Amaral	Khaeo Ei Khun	Shrub	Native	MD	HW, RT, SM	0.17	TJ373
Ochnaceae	*Ochna integerrima* (Lour.) Merr.	Chang Nao	Tree	Native	MD	RT	0.13	TJ374
Rhamnaceae	*Ziziphus cambodiana* Pierre	Nam Phlong	Shrub	Native	FD	FT	0.20	TJ375
Rubiaceae	*Gardenia sootepensis* Hutch.	Kham Mok Luang	Tree	Native	ON	WP	0.27	TJ376
Rubiaceae	*Paederia linearis* Hook.f.	Khruea Tot Ma	Climber	Native	FD	LV	0.23	TJ377
Rubiaceae	*Ridsdalea wittii* (Craib) J.T.Pereira	Mak Mo	Tree	Native	FD, MD	FT, HW, RT	0.20	TJ378
Rutaceae	*Clausena excavata* Burm.f.	Sa Mat	Shrub	Native	MD	IR, LV, RT	0.17	TJ379
Rutaceae	*Clausena harmandiana* (Pierre) Pierre ex Guill.	Song Fa	Herb	Native	MD	RT	0.13	TJ380
Salicaceae	*Flacourtia indica* (Burm.f.) Merr.	Mak Ben	Tree	Native	FD	FT	0.20	TJ381
Stemonaceae	*Stemona tuberosa* Lour.	Nhon Tai Yak	Climber	Native	MD	RT	0.20	TJ382
Verbenaceae	*Stachytarpheta jamaicensis* (L.) Vahl	Phan Ngu Khiao	Herb	Introduced	AF, MD	WP	0.13	TJ383

Note: Utilization: AF: animal fodder, AP: appliances, FD: food, FL: fuel, MP: medicine, ON: ornamental purpose, RC: ritual and ceremonies. Used parts = BA: bark, FT: fruits, HW: heartwood, IR: inflorescences, LV: leaves, RT: roots, SM: stem, WP: whole plant

Utilization of plants

The Use Value (UV) index of various plant species in the study area was calculated to assess their significance to local communities. The UV index ranges from 0.07 to 0.40 (Table 1), reflecting varying levels of importance based on the number of informants and their reported uses of the species. The species with the highest UV index was *C. gigantea* (UV = 0.40), indicating its considerable importance in the region, followed by *Urceola polymorpha* (Pierre) D.J.Middleton & Livsh. (UV = 0.37) and *Polyalthia evecta* (Pierre) Finet & Gagnep. (UV = 0.33). A substantial portion of the species had UV index ranging from 0.20 to 0.30, suggesting moderate usage and significance within the local community. These species included *Dipterocarpus intricatus* Dyer, *Leucaena leucocephala* (Lam.) de Wit, and *Bauhinia saccocalyx* Pierre (UV = 0.27), among others. Several species showed lower UV values, indicating limited or specialized use, such as *Helicteres hirsuta* Lour. (UV = 0.07), *Memecylon scutellatum* (Lour.) Hook. & Arn. (UV = 0.10), and *E. tomentosus* (UV = 0.10).

The plant species utilization in the research site demonstrates a wide variety of applications across different categories (Figure 3). The largest number of species (18 species) was recorded for medicinal purposes, highlighting the importance of plants in local healthcare. Twelve species were identified for food use, while four species were used for fuel. Additionally, 3 species were utilized for animal fodder and another 3 for ornamental purposes. Two species each were reported for use in appliances and in rituals and ceremonies.

Animal fodder

The plants used as animal fodder in the community include *Commelina benghalensis* L., *L. leucocephala,* and *Stachytarpheta jamaicensis* (L.) Vahl (Table 1). These species provide essential nutrients for livestock, supporting local agricultural practices. *Leucaena leucocephala* is especially valued for its protein-rich leaves, while *C. benghalensis* and *S. jamaicensis* are commonly used for their availability and nutritional benefits. These plants play a vital role in feeding animals and sustaining the community's farming systems.

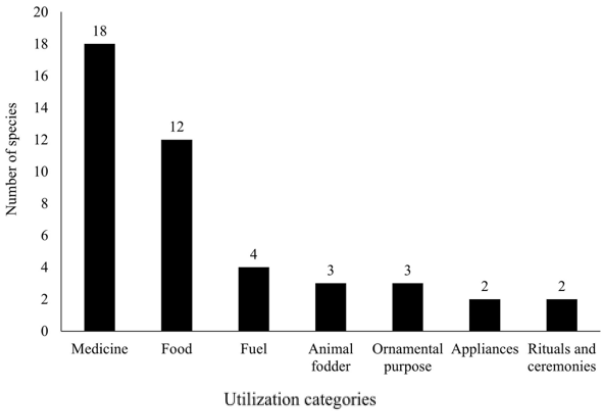

Figure 3. Utilization categories of plants used by villagers in Ban Nongtae Community Forest, Ban Dan District, Buri Ram Province, Thailand

Appliances

The following plants are utilized in the production of electrical appliances, with various parts of each plant serving distinct functions (Table 1). Different parts of *D. intricatus* are used for various purposes. The trunk, known for its durability and strength, is particularly valued in construction, furniture making, and the production of household appliances. Meanwhile, the fruits of the *Bombax anceps* Pierre, which contain natural fibers, are commonly used to produce pillows and mattresses. These plants contribute significantly to the creation of functional products and tools, with each part being processed into materials that are suitable for industrial use. Through this versatile application, they play an important role in meeting the demands of modern production and everyday living.

Food

A variety of plant species are used primarily as food sources by the community, each providing different parts of the plant for consumption (Table 1). *Polyalthia evecta* is utilized for its fruits, which the local people commonly eat. Similarly, *Ziziphus cambodiana* Pierre*,* and *R. wittii* are valued for their fruits, which form an important part of the local diet. *Flacourtia indica* (Burm.f.) Merr. also provides fruits that are consumed as food. Some plants offer multiple edible parts, such as *U. polymorpha* provides both fruits and leaves, which are used in local cuisine. *Leucaena leucocephala* is another plant that contributes both fruits and leaves, making it a versatile food source. *Oxystelma esculentum* (L.f.) Sm. offers its inflorescences and leaves for consumption, reflecting its role as a key food resource. Several plants are used specifically for their leaves, such as *Coccinia grandis* (L.) Voigt which is known for its leaves, which are incorporated into local dishes. *Bauhinia saccocalyx* and *Senna garrettiana* (Craib) H.S.Irwin & Barneby are also used for their leaves in various culinary preparations. *Careya arborea* Roxb. provides leaves that are eaten in the community. Finally, *Paederia linearis* Hook.f. is used for its roots, which are an important part of the diet in the region.

The plant species used by the community exhibit a variety of edible parts, which contribute to the local diet. Fruits and leaves are the most commonly utilized parts, with each accounting for 33.33% of the species, highlighting their central role in the community's food sources. A smaller proportion of species provide both fruits and leaves, making up 16.67% of the total, showcasing the versatility of these plants. Additionally, 8.33% of the species are valued for a combination of inflorescences and leaves, while the remaining 8.33% provide roots, which are also an important food resource.

Fuel

Several species with specific parts of each being harvested for energy production (Table 1). *Dipterocarpus intricatus* is primarily tapped for its latex, which serves as a valuable source of fuel. *Leucaena leucocephala*, commonly known for its fast growth and nitrogen-fixing properties, utilizes its stems as a significant fuel source. Similarly, *S. garrettiana* is another plant where the stem is the primary

part used for fuel. Lastly, *B. anceps* also relies on its stems for fuel production. These plants, with their diverse parts being used for fuel, contribute to sustainable energy sources, particularly in regions where traditional fuelwood is scarce or difficult to obtain.

Medicine

A total of 18 species are recognized for their medicinal properties, with various parts of each plant being utilized for therapeutic purposes (Tables 1 and 3). They are employed in the treatment of a wide range of conditions, highlighting their significance in local healthcare systems. The use of these plants underscores the importance of preserving traditional medicinal knowledge and ensures the continued relevance of these natural remedies in contemporary health practices.

Ornamental purpose

Bauhinia saccocalyx, *S. garrettiana*, and *Gardenia sootepensis* Hutch. are plants commonly used for ornamental purposes (Table 1). *Bauhinia saccocalyx* is admired for its striking flowers and is often grown for its aesthetic appeal in gardens and landscapes. Similarly, *S. garrettiana* is valued for its vibrant appearance and decorative qualities, making it a popular choice for ornamental planting. *Gardenia sootepensis* is also cultivated for its beautiful flowers and pleasant fragrance, enhancing the visual and sensory appeal of outdoor spaces. These plants are not only appreciated for their beauty but also contribute to the decorative and aesthetic value of the environment.

Rituals and ceremonies

Calotropis gigantea and *D. intricatus* are plants commonly used in rituals and ceremonies (Table 1). *Calotropis gigantea* holds a significant place in cultural practices, particularly in religious and spiritual ceremonies. Its flowers are often used to create *Bai Sri* (a rice offering) for worshiping Buddha, as well as in other ceremonies like the Bai Sri Su Khwan (wrist-binding ceremony). Similarly, *D. intricatus* plays a valued role in rituals, especially during the Bun Pha Wet ceremony. Its flowers are used as decorations in the ceremony's sacred space. These plants are not only important for their cultural significance but also serve as symbols of the local community's beliefs and traditions.

Informant consensus factor (F_{ic}) of medicinal plants

The Informant Consensus Factor (F_{ic}) values for medicinal plants used in Ban Nongtae Community Forest illustrate the degree of agreement among informants regarding the therapeutic application of various species (Table 2). The highest F_{ic} values (1.00) were observed in the categories of central nervous system (1 species, 3 use reports) and respiratory system (1 species, 4 use reports), indicating complete consensus among informants in using a single plant species for these ailments. High but slightly lower F_{ic} values were recorded in the categories of musculoskeletal and joint diseases (F_{ic} = 0.82; 3 species, 12 use reports) and drugs used in poisoning and toxicology (F_{ic} = 0.80; 2 species, 6 use reports), suggesting relatively strong agreement with some diversity in plant use. The infections category showed a F_{ic} of 0.74 (10 species, 36 use reports), reflecting moderate consensus likely due to the wide range of plant species used for treating various infections. Lower F_{ic} values were found in categories with greater diversity in plant usage. These include the gastrointestinal system (F_{ic} = 0.67; 6 species, 16 use reports), nutrition and blood (F_{ic} = 0.67; 3 species, 7 use reports), ear, nose, oropharynx, and oral cavity (F_{ic} = 0.64; 5 species, 12 use reports), obstetrics, gynecology, and urinary-tract disorders (F_{ic} = 0.64; 5 species, 12 use reports), and skin disorders (F_{ic} = 0.63; 4 species, 9 use reports). These lower values suggest more varied knowledge and preferences among informants, with multiple plant species used to address the same health concerns. The F_{ic} values indicate that consensus is strongest when a single plant is widely recognized for a particular ailment, while more diverse use of multiple species tends to lower agreement levels, reflecting the breadth of traditional medicinal knowledge in the community.

Fidelity level (FL) of medicinal plants

A total of 18 species were identified for medicinal use in the study area (Tables 1 and 3). Among them, *C. gigantea* demonstrated the highest Fidelity Level (FL) of 40, highlighting its significant role in treating symptoms of cough, cold, asthma, and fever. *Campylospermum serratum* (Gaertn.) Bittrich & M.C.E.Amaral followed with an FL of 33.33, while *Clausena harmandiana* (Pierre) Pierre ex Guill. had an FL of 60, indicating their moderate to high importance for medicinal purposes, especially for treating various ailments such as aches, pains, and gastrointestinal issues. Several species were particularly notable for their use in treating fever.

Table 2. Informant consensus factor (F_{ic}) of medicinal plants used by villagers of Ban Nongtae Community Forest

Group of ailments	Total number of use reports (n_{ur})	The number of plant species (n_t)	F_{ic}
Central nervous system	3	1	1.00
Respiratory system	4	1	1.00
Musculoskeletal and joint diseases	12	3	0.82
Drugs used in poisoning and toxicology	6	2	0.80
Infections	36	10	0.74
Gastro-intestinal system	16	6	0.67
Nutrition and blood	7	3	0.67
Ear, nose, oropharynx, and oral cavity	12	5	0.64
Obstetrics, gynaecology, and urinary-tract disorders	12	5	0.64
Skin	9	4	0.63

Table 3. Fidelity Level (FL) of medicinal plants used by villagers of Ban Nongtae Community Forest

Scientific name	Ip	Iu	FL	Used parts	Preparation	Method of uses	Ailments	Group of ailments
Calotropis gigantea (L.) W.T.Aiton	2	5	40.00	Inflorescence	Dry and boil in water, filter to get only the liquid	Drink	Treat symptoms of cough, cold, and asthma	Ear, nose, oropharynx, and oral cavity
	3	5	60.00	Root	Boil in water, filter to get only the liquid	Drink	Treat fever	Infections
Campylospermum serratum (Gaertn.) Bittrich & M.C.E.Amaral	2	6	33.33	Root	Boil in water, filter to get only the liquid	Drink	Treat diabetes	Nutrition and blood
	3	6	50.00	Stem	Boil in water, filter to get only the liquid	Drink	Treat aches and pains	Musculoskeletal and joint diseases
	1	6	16.67	Heartwood	Boil in water, filter to get only the liquid	Drink	Treat urinary retention	Obstetrics, gynaecology, and urinary-tract disorders
Clausena excavata Burm.f.	5	9	55.56	Root	Boil in water, filter to get only the liquid	Drink	Treat parasitic infections	Infections
	2	9	22.22	Leave	Boil in water, filter to get only the liquid	Drink	Treat fever	Infections
	2	9	22.22	Inflorescence	Boil in water, filter to get only the liquid	Drink	Treat phlegm	Ear, nose, oropharynx, and oral cavity
Clausena harmandiana (Pierre) Pierre ex Guill.	3	5	60.00	Root	Boil in water, filter to get only the liquid	Drink	Treat headaches	Central nervous system
	2	5	40.00	Root	Combine with the root of *Cladogynos orientalis*, boil in water, and filter to obtain only the liquid.	Drink	Treat colic	Gastro-intestinal system
Ellipanthus tomentosus Kurz	1	8	12.50	Heartwood	Boil in water, filter to get only the liquid	Drink	Treat stomach pain	Gastro-intestinal system
	3	8	37.50	Root	Boil in water, filter to get only the liquid	Drink	Helps nourish the body postpartum	Obstetrics, gynaecology and urinary-tract disorders
	4	8	50.00	Stem	Boil in water, filter to get only the liquid	Drink	Treat asthma	Respiratory system
Erythroxylum cambodianum Pierre	5	5	100.00	Root	Boil in water, filter to get only the liquid	Drink	Treat aches and pains	Musculoskeletal and joint diseases
Helicteres hirsuta Lour.	1	6	16.67	Heartwood	Boil in water, filter to get only the liquid	Drink	Treat itchy skin rashes	Skin
	2	6	33.33	Heartwood	Boil in water, filter to get only the liquid	Drink	Treat symptoms of cough, cold, and asthma	Ear, nose, oropharynx, and oral cavity
	3	6	50.00	Fruit	Boil in water, filter to get only the liquid	Drink	Treat parasitic infections	Infections
Heliotropium indicum L.	2	4	50.00	Stem	Boil in water, filter to get only the liquid	Drink	Treat stomach pain	Gastro-intestinal system
	2	4	50.00	Inflorescence	Boil in water, filter to get only the liquid	Drink	Treat menstrual disorders	Obstetrics, gynaecology, and urinary-tract disorders
Holarrhena pubescens (Buch.-Ham.) Wall. ex G.Don	3	9	33.33	Bark	Boil in water, filter to get only the liquid	Drink	Treat phlegm	Ear, nose, oropharynx, and oral cavity
	2	9	22.22	Bark	Boil in water, filter to get only the liquid	Drink	Treat diabetes	Nutrition and blood
	4	9	44.44	Inflorescence	Boil in water, filter to get only the liquid	Drink	Treat parasitic infections	Infections
Memecylon scutellatum (Lour.) Hook. & Arn.	5	7	71.43	Root	Boil in water, filter to get only the liquid	Drink	Treat stomach diseases	Gastro-intestinal system
	2	7	28.57	Stem	Boil in water, filter to get only the liquid	Drink	Diuretics	Obstetrics, gynaecology, and urinary-tract disorders
Ochna integerrima (Lour.) Merr.	3	8	37.50	Root	Boil in water, filter to get only the liquid	Drink	Treat diabetes	Nutrition and blood
	5	8	62.50	Root	Boil in water, filter to get only the liquid	Drink	Treat parasitic infections	Infections

Ridsdalea wittii (Craib) J.T.Pereira	3	7	42.86	Root	Boil in water, filter to get only the liquid	Drink	Treat fever	Infections
	4	7	57.14	Heartwood	Boil in water, filter to get only the liquid	Drink	Diuretics	Obstetrics, gynaecology, and urinary-tract disorders
Senna occidentalis (L.) Link	4	6	66.67	Root	Boil in water, filter to get only the liquid	Drink	Detoxify poisons and poisonous mushrooms	Drugs used in poisoning and toxicology
	2	6	33.33	Leave	Boil in water, filter to get only the liquid	Drink	Treat fever	Infections
Solena amplexicaulis (Lam.) Gandhi	3	6	50.00	Leave	Pound until fine, mix with a little water, then squeeze out the juice and apply to the affected area.	Apply to skin	Treat itchy skin	Skin
	3	6	50.00	Leave	Eat fresh		Treat symptoms of indigestion and stomach bloating	Gastro-intestinal system
Stachytarpheta jamaicensis (L.) Vahl	5	10	50.00	Whole plant	Boil in water, filter to get only the liquid	Drink	Treat fever	Infections
	2	10	20.00	Whole plant	Boil in water, filter to get only the liquid	Drink	Treat parasitic infections	Infections
	3	10	30.00	Whole plant	Boil in water, filter to get only the liquid	Drink	Treat phlegm	Ear, nose, oropharynx and oral cavity
Stemona tuberosa Lour.	3	4	75.00	Root	Boil in water, filter to get only the liquid	Drink	Treat skin disease	Skin
	1	4	25.00	Root	Boil in water, filter to get only the liquid	Drink	Treat parasitic infections	Infections
Suregada multiflora (A.Juss.) Baill.	2	5	40.00	Root	Boil in water, filter to get only the liquid	Drink	Treat skin disease	Skin
	3	5	60.00	Bark	Boil in water, filter to get only the liquid	Drink	Laxative	Gastro-intestinal system
Trigonostemon reidioides (Kurz) Craib	2	7	28.57	Root	Grind with the water	Drink	Detoxify poisons and poisonous mushrooms	Drugs used in poisoning and toxicology
	4	7	57.14	Root	Grind with the water	Apply to skin	Treat sprains	Musculoskeletal and joint diseases
	1	7	14.29	Root	Boil in water, filter to get only the liquid	Drink	Treat tuberculosis	Infections

Clausena excavata Burm.f. (FL = 22.22) and *R. wittii* (FL = 42.86) were commonly used, particularly for treating fever and parasitic infections. *Senna occidentalis* (L.) Link (FL = 66.67) also had a high FL, underscoring its common use in treating fever and poisons. *Erythroxylum cambodianum* Pierre (FL = 100) emerged as one of the most valued species, particularly for treating aches and pains, reflecting its high Fidelity Level and specific use in musculoskeletal and joint diseases. On the other hand, species such as *H. hirsuta* (FL = 16.67) and *Solena amplexicaulis* (Lam.) Gandhi (FL = 50) were commonly used for treating skin-related ailments, such as itchy rashes and skin diseases. Several species also demonstrated notable use in addressing gastrointestinal issues. *M. scutellatum* (FL = 71.43) and *Heliotropium indicum* L. (FL = 50) were frequently used to treat stomach-related ailments like pain, indigestion, and bloating. *Suregada multiflora* (A.Juss.) Baill. (FL = 60) was also used for constipation and other digestive issues. For musculoskeletal and joint diseases, species like *C. serratum* (FL = 50) and *Trigonostemon reidioides* (Kurz) Craib (FL = 57.14) played significant roles. Notably, *C. serratum* was also reported for its effectiveness in treating diabetes, demonstrating its wide-ranging medicinal applications. In treating parasitic infections, species such as *S. jamaicensis* (FL = 50) and *Holarrhena pubescens* (Buch.-Ham.) Wall. ex G.Don (FL = 44.44) were prominently used, highlighting their essential role in local healthcare practices.

Overall, the Fidelity Level (FL) of the species in the study demonstrates the diverse and critical role these plants play in the health care practices of local communities. Some species, such as *E. cambodianum* and *S. occidentalis*, exhibit multiple medicinal applications across various groups of ailments.

Discussion

This study documented 33 plant species across 20 families in Ban Nongtae Community Forest, with Apocynaceae, Fabaceae, and Rubiaceae as the most prominent families. These species serve diverse purposes—including food, medicine, rituals, and construction—reflecting the multifunctional use of plant resources by the local community. Compared to ethnobotanical studies in nearby areas, species diversity here is lower. For example, Appamaraka et al. (2023) recorded 44 species from 28 families in Don Pu Ta Forest, Sakon Nakhon Province, and Saensouk et al. (2025c) documented 109 species from 48

families in Lao Isan, Maha Sarakham Province. Niamngon et al. (2024) reported 317 species across 89 families in Pho Chai District, Roi Et Province, possibly reflecting more intensive agricultural practices and cultural traditions. Despite fewer species, Ban Nongtae displays notable diversity in use categories beyond medicine, such as food, ritual, and construction, underscoring the forest's cultural importance. In contrast, other areas emphasize medicinal or economic plants depending on their ecological and socio-economic contexts (Panyadee et al. 2022). While threats from urbanization endanger traditional knowledge elsewhere (Niamngon et al. 2024), Ban Nongtae's smaller community still preserves deep ethnobotanical knowledge, illustrating the vital role of community forests as refuges of biocultural heritage.

Life form strongly influences vulnerability to overharvesting. Shrubs (36.36%) and trees (33.33%) dominate the species recorded, followed by climbers and herbs. Considering life form alongside the Use Value (UV) and harvested plant parts offers insight into conservation risks. Species harvested primarily for fruits or leaves generally face lower risk, as these parts can be collected sustainably. Conversely, harvesting roots, bark, or heartwood often damages or kills plants, elevating vulnerability. Trees and woody climbers, which grow and regenerate slowly, are particularly at risk when harvested for such parts. Herbs and fast-growing shrubs, usually collected for leaves or fruits, present lower risks. The identification of high-risk species highlights the urgent need for conservation measures such as promoting non-lethal harvesting, cultivation, and community education to sustain biodiversity and traditional use (Crausbay and Martin 2016). Although less represented, climbers and herbs contribute to forest structure, nutrient cycling, and habitat complexity (Götmark et al. 2016).

The predominance of native species (87.88%) indicates a healthy, stable forest ecosystem well adapted to local conditions (Shelef et al. 2017). The presence of introduced species (12.12%) reflects human influence and potential ecological disruption through competition or habitat alteration (Rodewald and Arcese 2016). Monitoring these introduced taxa is important to maintain ecological balance.

The Use Value (UV) index reveals the relative importance of species to the community. *C. gigantea* emerged as particularly significant, alongside species such as *U. polymorpha* and *P. evecta*, which play vital roles in daily life. The range of UV values reflects differing degrees of utility, from multifunctional species to those with more specialized uses (Darmastuti et al. 2024). The wide variety of plant uses—medicinal, nutritional, ritual, construction, and more—demonstrates the forest's integral role in sustaining livelihoods and cultural practices (Mapaya et al. 2022).

Medicinal plants hold a prominent place, with 18 species used for healthcare. High Informant Consensus Factor (F_{ic}) values for conditions such as central nervous system and respiratory ailments suggest strong agreement on effective treatments (Ambu et al. 2020). Moderate F_{ic} values in categories like musculoskeletal and gastrointestinal issues indicate diverse plant usage, while lower values in more complex health categories reflect variable practices. Species like *C. gigantea*, *C. harmandiana*, and *S. occidentalis* serve key medicinal roles, while others such as *E. cambodianum* and *M. scutellatum* are important for specific ailments. Multifunctional species such as *C. serratum* underscore the diversity of traditional medicine. These findings highlight the need to conserve medicinal plants for both community health and potential drug discovery.

Beyond medicine, plants support food security (e.g., *P. evecta*, *Z. cambodiana*), animal fodder (*L. leucocephala*, *C. benghalensis*), and material culture (*D. intricatus*, *B. anceps*), illustrating a broad spectrum of community reliance (Hidayat 2017; Duguma 2020; Radha et al. 2022). Such multifunctionality strengthens the socio-economic resilience of the community.

In conclusion, the Ban Nongtae Community Forest in Buri Ram Province serves as a vital repository of plant diversity and traditional ecological knowledge. Although species richness is modest compared to nearby regions, the multifunctional use of plants for medicine, food, rituals, and construction reflects the community's deep ecological relationships. Most species are native and harvested sustainably, but several high-use taxa, particularly trees and woody climbers valued for their roots or bark, face elevated conservation risks. Three key insights emerge from the study. First, even small-scale community forests can support a rich mosaic of culturally significant plant uses. Second, integrating data on life form, use value, and plant parts offers a practical framework to assess conservation vulnerability. Third, strong informant consensus around certain medicinal species reflects the resilience of local knowledge systems. To ensure long-term sustainability, conservation efforts should prioritize the cultivation of high-risk species, promote non-destructive harvesting practices, and strengthen knowledge transmission within the community. Protecting such forests is essential not only for biodiversity conservation but also for maintaining the cultural and ecological resilience of local livelihoods.

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Traditional plant use and cultural practices sustaining Nyishi livelihoods in Northeast Himalayan region, India

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Abstract. *Taba, Pant N, Akash. 2025. Traditional plant use and cultural practices sustaining Nyishi livelihoods in Northeast Himalayan region. Asian J Ethnobiol 8: 192-202.* The Northeastern Himalaya has a wealth of plants that have been used by the forest dwelling communities. This huge valuable knowledge of these communities is yet to be documented. The present study explored ethnobotanical usage of plants, plant-based traditional skills and technologies by Nyishi tribes in Lower Subansiri District in Arunachal Pradesh, India. An extensive field study was conducted from 2021 to 2023 in the towns of Yazali and Yachuli. Field survey included semi-structured interviews, questionnaire-based survey, focused group discussion, participatory observation, interview of primary respondents and open discussion to provide the data on various traditional plant technologies used in food preparation, cooking, homemade storage structures, fishing, hunting, drying and conservation pattern of related biocultural resources. In the present study, ethnobotanical data were recorded for 39 plant species belonging to 22 families. Information regarding their botanical name, family, common name, local name, and their ethnobotanical uses, along with various indigenous uses of plants, along with traditional tools, traps, utensils, ornaments and accessories, along with food habits used by the Nyishi tribe for sustainability and livelihood. Additionally, observations were made to assess the process of making and using plant technologies.

Keywords: Arunachal Pradesh, ethnoecological record, ethno-ecological, ethnomedicinal plants, Nyishi tribe

INTRODUCTION

Ethnomedicinal plants are used by a large number of people worldwide, in both developing and developed countries (WHO 2002; Brandão 2006). All ethnic groups rely on plants around them for healthcare practices, primarily based on observation, need, and trial and error (Kunwar et al. 2018). The Indian Himalayas harbor approximately 8,000 species of angiosperms, out of which 1,748 species of plants have been used for various pharmacological purposes (Malik et al. 2015). It has been estimated that about 84% of the total rural population mainly depends on wild plants for curing different diseases (Ahmad et al. 2016), which passed generation after generation (Khan et al. 2015). In the past, it was observed that indigenous traditional knowledge of medicinal plants has long been a source of livelihood sustainability for the tribal population.

In India, approximately 65% of the population depends on forests for folk medicines (Timmermans et al. 2003). The indigenous knowledge is often transferred orally, a cultural practice that is frequent in less developed areas (Akash et al. 2020a). Northeast is an important part of the India Himalayan region, which is known for its rich biodiversity and huge cultural diversity as well as indigenous traditional knowledge. The State Arunachal Pradesh, also popularly known as "The Land of the Rising Sun" is the largest Himalayan state in Northeast India. It is located between 26°28'-29°30'N latitude and 91°30'E longitude. The state is also known as "The Land of the Downlit Mountains". The state of Arunachal Pradesh is rich in its floristic heritage, with ethnobotanical, ecological, and economic significance distributed along different altitudinal gradients, ranging from tropical to snow-clad alpine mountains. There are 25 districts in Arunachal Pradesh, including the Lower Subansiri District. The state is inhabited by more than 26 major tribes and over 100 sub-tribes. The tribal people live in balance with nature and maintain a very close link between humans and nature (Sharma et al. 2014).

Due to the lack of a modern healthcare system, the villagers in the remote areas of Arunachal Pradesh depend on local traditional practitioners and folk medicine. The tribal people have personal classification, identification, and use of medicinal plants. However, the ethnobotanical plants used in folk healing and their indigenous uses have not yet been explored and categorized for any community in Arunachal Pradesh (Tag and Das 2007; Murtem 2014). There are unknown medicinal plants or folk medicines that still require taxonomic and pharmacological documentation for database and clinical trial validity. The culturally important plant-based tools, such as chairs, tables, kitchen utensils, fishing nets and tools, dishes, and storage and preservation tools, made of wood, cane, and bamboo, are more popular and economically viable among the Nysihi tribe. The role of plant materials and technology in trade has also become increasingly clear in recent years in Arunachal Pradesh. The importance of plant-based foods and medicines to the Nysihi people is well appreciated; however, the documentation of plants used in traditional handicraft technology among the Nysihi was found to be

overlooked (Ramakrishnan et al. 2002).

Keeping all these in consideration, the present study was undertaken to document plant-based traditional skills, technologies and ethnobotanical usage of plants practiced by the Nyishi tribes of Lower Subansiri District, Arunachal Pradesh. Despite the rich ethnobotanical knowledge and traditional plant-based technologies practiced by the Nyishi tribe in the Northeastern Himalayas, there is a significant lack of systematic documentation and understanding of how these practices support sustainable livelihoods and biocultural conservation.

MATERIALS AND METHODS

Study area

The present study was conducted from 2021-2023 in the Lower Subansiri District of Arunachal Pradesh. Data collection was conducted in Yazali and Yachuli towns in the Lower Subansiri District (Figure 1). Geographically, the Lower Subansiri District is located between 92°40 and 94°21 E and 26°55 and 28°21 N, covering an area of 3,460 km^2. Generally, December to February is cold winter season where the temperature reaches 3.8°C and March to May is pre-monsoon season. Nyishi are one of the most dominant and traditionally rich tribes in Lower Subansiri District. The Nyishi are the sons of Abo Tani, the first ancestor and his ideal son, Ato Niya. They are one of the largest tribes belonging to the Tani group in Arunachal Pradesh, constituting one-third of the population of Arunachal Pradesh and distributed in various villages of seven districts. Although Nyishi people have been exposed to modernization in recent days, agricultural activities are still performed traditionally in most parts of the Nyishi-inhabited area. It is the main occupation, and Jhum cultivation remains the predominant method of cultivation. They celebrate Nyokum Yullo as their main festival. Like other tribes in Northeast India, boiled rice is a staple food for the Nyishi. Boiled rice is complemented with various green vegetables and bamboo shoots.

Data collection

A field survey was conducted to record the ethnoecological data, along with exploring their traditional skills and technologies sustaining the livelihood. Ten villages (i.e., Kebi, Sekhi, Depo, Seer, Pitapool, Peni, Zara, Migo, Peker, and Deli Hapa) were selected on the basis of forest cover, ethnicity and people's dependency on forest resources and traditional plant technologies. Data were gathered from 80 respondents, comprising 40 females and 40 males, with an age range of 40-65 years. Informants were grouped into 40-50 years and 50-65 years to gather the information. This age group showed a marked interest in contributing knowledge related to traditional tools and techniques. More comprehensive interviews provided data on various traditional plant technologies used in food preparation, cooking, homemade storage structures, fishing, hunting, drying, and conservation patterns of related biocultural resources. Additionally, observations were made to document the process of creating and utilizing plant technologies. Deeper observations by staying in Nyishi houses in forest areas were made to learn about the cultural aspects of utensils, handicrafts and other technologies used in daily life. For qualitative analysis, semi-structured interviews were conducted to obtain more detailed information. The interviews were also conducted at the district handicrafts center and cooperatives to understand the economics, various projects run by the state and central governments, and the network of handicrafts makers. During the field visit, translation of the local nomenclature of plants and documentation of plant-based traditional knowledge were assisted by local knowledge holders, field guides and traditional healers of Nyishi community who had expertise in their local dialect, indigenous cultural system and local ethnoecological landscape. Data were collected with ethnobotanical aspects, i.e., local names, common names, parts used, mode of use, habits, habitats of each plant and their indigenous uses were recorded in field notebooks. Locally available medicinal plants were collected for identification and herbarium preparation following standard methods (Jain and Rao 1977).

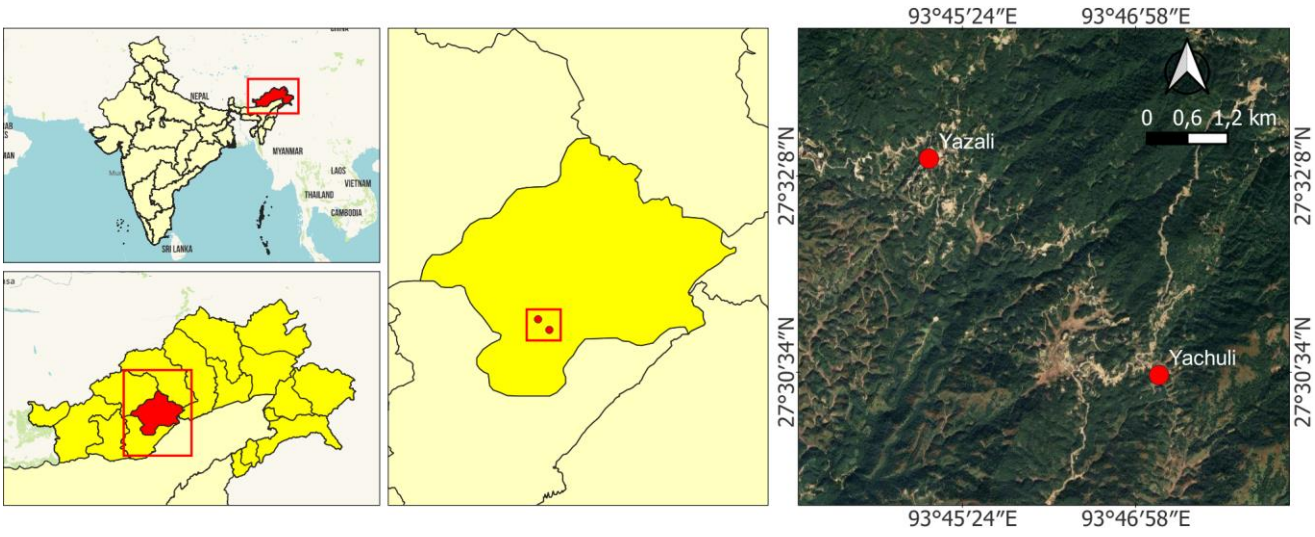

Figure 1. Map of study area in Yazali and Yachuli, Lower Subansiri District, Arunachal Pradesh, India

Data analysis

For quantitative analysis, Analysis of Variance (ANOVA) was performed using SPSS version 20 for statistical analysis to test for significant differences among parameters. For qualitative analysis, all the parameters of plant-based tools and techniques that sustain the life of Nishi were compiled.

RESULTS AND DISCUSSION

The Nyishi people of Lower Subansiri have a tradition of artistic craftsmanship and a wide variety of handicraft practices, including weaving, painting, pottery, metalwork, basketry, and wood carving (Table 1). The crafting of mats, wooden vessels and pottery speaks itself eloquently about their skills in handicraft technology. Crafting in the Nyishi society is exclusively done by the male folk, and all of the craftsmen under the present study were observed to be male. The raw materials, bamboo, wood and cane, were always collected from the forest areas by them. They are able to recognize trees and bamboo of interest to them. One-way ANOVA was performed with the parameters of consumption, harvest, and conservation of wild and edible plants, which were recorded as significantly different ($P < 0.001$).

Plant-based technology and livelihood of Nyishi tribe

Cane and bamboo-based plant technology of the Nyishi tribe includes hats of different sizes and shapes, various kinds of baskets, cane vessels and a wide variety of cane belts, elaborately woven brassier of cane and fiber, bamboo mugs with carvings (Figure 2). It was observed from the study that Nyishi were mastered in the technique of basketry, storage items and kitchen utensils, and the design of such items among the villagers has been found to be entirely need-based, practical and aptly suitable to their socio-cultural and geographical landscape. Metallic work, carpentry, and pottery are other crafts practiced by the Nyishi people. The arts of crafting traditional utensils and handicraft items of immense utility from the forest hood, clay and metal are inherited from ancient wisdom, which is still practiced in Nyishi locality. The plant-based crafts, such as *egin* (bamboo or cane-made basket for carrying rice, etc.), *paha* (for carrying firewood), *muda* and *pirah* (bamboo or cane made for sitting), *nara* (cane made for carrying food items and beverages while going for work or to forests), *opyi* (cane made for cleaning rice), *buhiya* (daw holder, made of cane), etc. (Figure 2), are mostly crafted by the male folk and form a source of income to Nyishi. Furthermore, various household items such as *pwter* (cane or bamboo made for house for chickens), *chipe* (local grinder for grinding rice made of wood), *chuha* (cane or bamboo made pockets), and *sahiya* (cane made local rope) are also used in their day-to-day life (Figure 2). In every household in remote areas, people possess skill to make these technologies and sell them in nearby towns. Some of the wooden, cane, and bamboo plant technology is sold through district handloom and handicraft centre. With the help of various central and state government sponsored training and entrepreneurship development schemes, an emphasis is given on plant technologies for capacity building and empowerment of Nyishi people.

Tools and traps used for hunting

The Nyishi resort to hunting in their leisure time in order to supplement their food requirements. The weapons commonly used and made by them are spears, bows, arrows, and daw (a flat iron piece with sharp edge on one side crafted in the form of sword, about 30-70 cm). The daw is a necessity tool in households. It is one of the most important tools as it is used in every aspect like in their day today life and also stands as a symbol of pride for in the people of this tribe. The bow and arrow used for hunting are known as *eel upu*. Some of the arrow's tips are fitted with sharp metallic head, which is caped with poison prepared from the roots of alpine herb (locally called omyi), *Aconitum ferox* Wall. ex Ser. and are carried in quivers of bamboo tubes. Such poison arrow is mostly used for killing large animals, such as bear, wild boar and lion. The paste of omyi poison used on arrow tip is prepared in special type of traditional utensil made of stone.

Table 1. Plant-based traditional tools used by Nyishi Tribe in Lower Subansiri District, Arunachal Pradesh, India

Category	Examples of tools/items	Material used	Main purpose
Agriculture and field	*Chucha*, *mudhu*, *appin*, *dekumpwchi*	Bamboo, clay, leaves	Sowing, seed storage, insect protection
Hunting and fishing	*Daw*, *eel upu* (bow & arrow), *ghurw* (trap), *edwr*, *quiver*, fishing nets, *salah*	Bamboo, cane, iron, poison plants	Hunting animals, trapping, fishing
Cooking and utensils	Chindhu, *phuniya*, *udu*, *durw*, *hukhu*, *harcha*, *opo patah*, *sahder*, *sab sohrw*	Bamboo, gourd, horn, clay	Cooking, eating, storing food and beverages
Storage and utility	*Hodo*, *dusin*, *huuch*, *lohdu*, *pwter*, *chuha*, *dimber*, *masap*, *sobku*	Bamboo, cane	Storing rice, salt, meat, chickens, fire tools
Crafting and handicrafts	*Egin*, *paha*, *muda*, *nara*, *opyi*, *toko-patta items*, *quercus*/Thaumatococcus leaves	Bamboo, cane, palm leaves	Weaving, sitting, roofing, food wrapping
Ornaments and identity	*Dumpin*, *rubin*, *belling*, *huhi*, *koji*, *bopiya*, *soruh*, *tasnara*, *setum*, *lolup*, *tammah*, *lurum*	Beads, cane, palm, leather, metal	Decoration, protection, ethnic identification

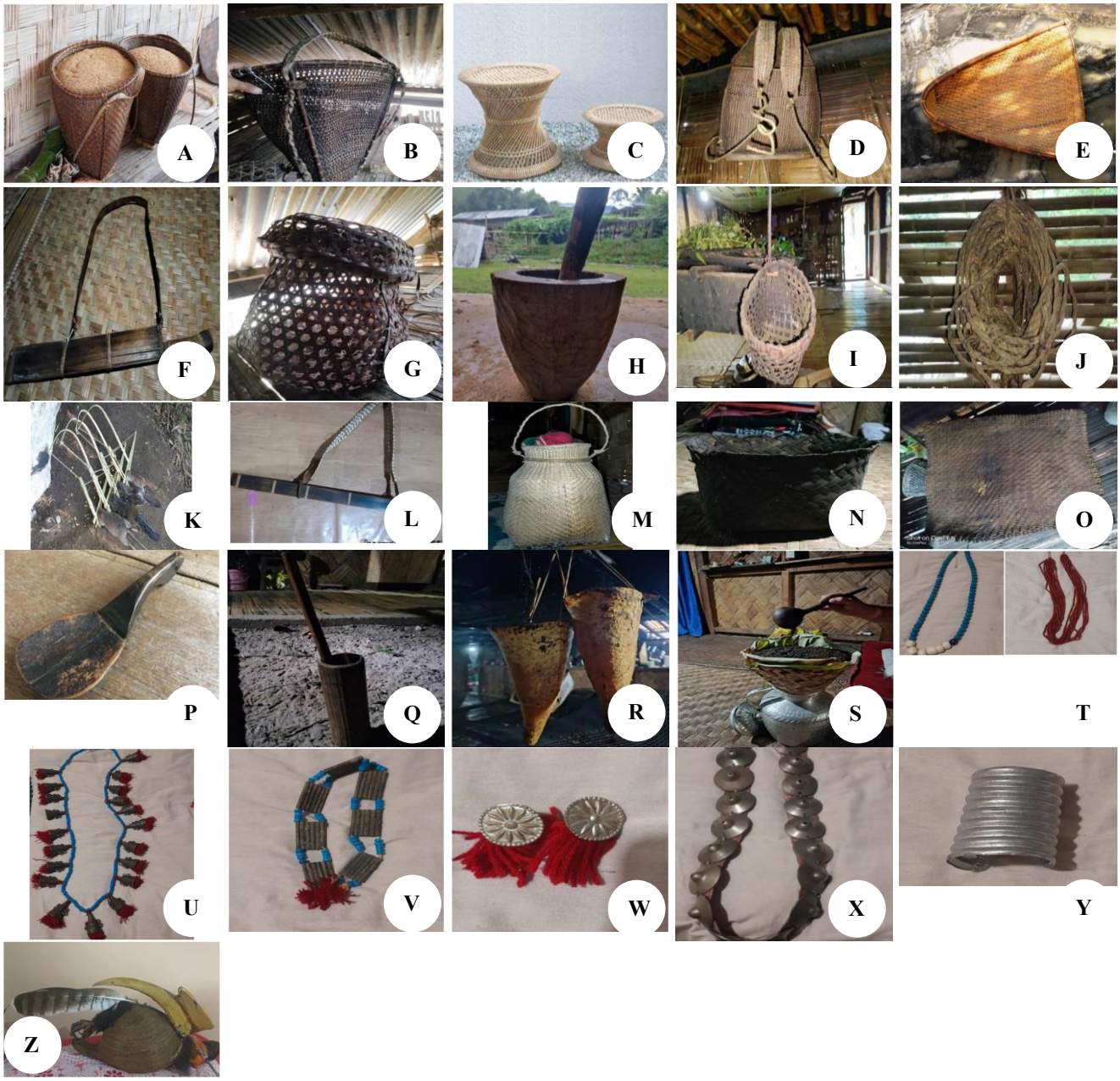

Figure 2. Traditional tools used by Nyishi tribes in Lower Subansiri District, Arunachal Pradesh, India. Note: A. *Egin* (for carrying rice), B. *Paha* (for carrying firewood), C. *Muda* (cane-made tool), D. *Nara* (local bagpack for men), E. *Opyi* (cane-made for winnowing rice), F. *Buhiya* (daw carrier), G. *Pwter* (house for chickens), H. *Chiphir* (local rice grinder), I. *Chuba* (small pockets for storage), J. *Sahiya* (local ropes), K. *Ghurw* (mouse and bird trap), L. *Salah* (locals word), M. *Dusin* (rice storage), N. *Huuch* (storage basket), O. *Appin* (local mat), P. *Puniya* (local spoon), Q. *Udu* (grinder), R. *Sabsohrw* (storage), S. *Sahder* (apongfilter), T. *Tasang* (local beads), U. *Maji*, V. *Dumpin* (female headgear), W. *Rubin* (earring), X. *Huhi* (local belt), Y. *Koji* (local bangles), Z. *Bopiya* (Nyishi headgear)

The villagers have their own indigenous ways of trapping animals and birds using traditional plant-based technologies. They make various traps, big and small, with or without valves, made of bamboo and cane for fishing and such trapping items are popularly known as edwr among the Nyishis. Fishing nets of various types, such as hand nets and cast nets, are also in use, which are made from locally available plant resources. The art of trapping wild rats using bamboo made traps called ghurw is quite popular among Nyishi tribe to protect their crops and vegetables in fields and in stores. This type of trap (ghurw) is also used to trap birds, squirrels, etc. in the forest. Salah (Nyishi sword) is made of iron and wood, long in shape, kept in the home and used in buya dance.

Traditional utensils and food habits

Some of the significant observations made during the field investigation were the dynamics of traditional utensils made from various locally available plant species and other ethnobotanical resources used as traditional items. In the early days, when the Nyishi were unfamiliar with modernization and its technologies, they were dependent only on the plant-

based technologies and developed various plant-based traditional skills. From their food habits to the utensils they used were plant-based. Although the new technologies are well introduced now, tribal people are still practicing traditional skills. Many household utensils were observed including *hodo* (large bamboo basket) used for the storage of wheat, rice, corn etc.; *dusin* (bamboo orcane basket) used for storing rice; *huuch* (small bamboo basket) used for measuring rice; *phuniya* (local spoon made of bamboo); *appin* (bamboo or cane made) local mat used as a carpet and also used in drying rice under sun; *dekumpwchi* (earthen pots made up of sticky clay) used for cooking rice and vegetables; *chindhu* (bamboo cylinder) used for cooking rice and fish mostly used while in forest or fields; *hukhu* (local plate made of bamboo); *lohdu* (made of bamboo) used for storing salt; *harcha* made of dried shell of wild bottle guard covered with cane trip used for carrying beverages like water and apong in Jhum field and storing apong; *opo patah* used as local jug for drinking apong or water; *mudhu* made of bamboo (small cylinder) carried by them tied in their waist and a tiny spark of fire with dried local leaves are placed together in this small cylinder which produces smoke for a long time which protects them from mosquitoes and insects while they work in the fields; *udu* and *durw* bamboo cylinder used for chutney and grinding spices respectively; *chucha* used for storing and also used by women in Jhum fields for carrying rice paddy grains while sowing; *masap* and *sobku* local pliers made of bamboo mainly used for working near the fire; *dimber* (bamboo or cane made) used for storing dried meat and it also plays a major role in marriage; *uju* made of deceased bottle guard used as jug mainly used for serving *apong*; *sab sohrw* (horns of Mithun) kept as a case for storing small things or money; *sahder* is mostly used in the filtration of apong. *Quercus* sp. and *Thaumatococcus daniellii* (Benn.) Benth. ex Eichler leaves are used for packing rice and used as a plate. These leaves are of two types, Kohum Ook and Hemir Ook, which are considered holy leaves and play an important role in the Nyokum yullo festival.

These are some examples of utilizing the bioresources of the surrounding in traditional utensils, arts, crafts, and food habits. The reason behind using such a range of traditional utensils made of plant resources is their intrinsic attachment to ecosystems and food habits. The special kind of flavor, keeping quality, and storage duration, for which traditional utensils are a source, are major reasons cited by experienced elders of the community. Traditional utensils are believed to be one of the main parts of a household property and are kept under the custodian of the older generation of the family. They are familiar with the history of origin and the traditional mythology and folklore associated with utensils. Having rice in Ook is considered tastier and good for digestion. With the availability of low-cost utensils, preservation of such traditional utensils is decreasing and thus losing their prestige and value to the young generation. In interior and remote villages, the Nyishi villagers are still using the traditional utensil made of wood and bamboo. However, the bamboo utensils are still used by the Nyishi people living in transitional socio-ecological systems because they are inexpensive and readily available. The dynamics of these factors are found more in remote villages. Various external factors such as influence of media, modernization, changing livelihood systems and various socio-political aspects, are weakening the traditional intrinsic value and skill of making plant technology.

Ornaments and accessories

In earlier days, the Nyishi tribe used to travel across countries like China and Tibet to obtain ornaments made from elephant teeth. Craftsmen and blacksmiths in these places were specialized individuals who created these ornaments for the local people. The way to those places was extremely dangerous, and local people used to face difficulties while travelling across the road. They used the barter system to get the ornaments or any other stuff they wanted in exchange for wild animal's body parts although it is a long-gone tradition now. As every female in any society would love jewels, the females of this tribe loved those handmade ornaments. Males of this tribe had their own preferences, such as decorating the cover of their swords with the hide of wild animals and also with the teeth of tigers. They also loved designs on their swords, but maintained the sleekness and sharpness of their sword simultaneously. The Nyishi tribe members usually like beads in jewelry known, as Tasang and use bells of different kinds, known as Maji. The ornament that women generally wear on their heads is called as a Dumpin. There are other special ornaments such as Rubin and belling that are used as earrings. They also adorn themselves with a belt made up of round discs, known as Huhi or Hufyi. The women often wear a various bangles Koji. Traditional dresses are marker of ethnic identity along with ornaments and other items for adoration for both male and female in traditional context as reported from various villages. These ornaments which has immense value were once had different significance in past during wars. Many of these ornaments or accessories are used as a protective gear in the area. For example, *bopiya* (headgear) is used as a helmet, *soruh* (local belt) for protecting their chest and waist, *tasnara* and *setum* made of palm tree and skin of wild yak, respectively, are used as a shield, Lolup (arm protection) and many other accessories like *eel upu* (bow and arrow), *olioh* (daw) local sword type are used as a weapon. Accessories like *tammah* (palm tree made belt) and *lurum* (cane made) are used for identification purposes for men.

Wildlife, culture, plant biodiversity, and skill

The integration of wildlife and plant biodiversity, which are life support systems for the Nyishi tribes and ethnicity, depict the degree of skill and imagination power in making handicrafts. For example, bamboo species such as *Dendrocalamus hookeri* Munro and *Bambusa vulgaris* Schrad. ex J.C.Wendl. are mostly employed in traditional house construction and used as ritual and cultural gift items offered to benevolent almighty gods during local festival such as *Nyokum* and *Lungte* apart from using them in crafting traditional handicraft items. Some of the indigenous species of perennial trees and palm species, like toko-patta (*Livistona jenkinsiana* Griff.) are considered multipurpose species.

For example, the leaves of took-patta are used after proper drying as a roofing material for local houses. The new shoots of toko-patta are used as vegetable, while unripe fruits are used as chutney. The leaves are also used in nursery as overhead shade. The entire plant is used as an ornamental and avenue plant, while the fibrous sheaths are utilized in the production of rope and water-resistant shields for shoulder bags. The cut stem is used as temporary log bridge to crossover village streams and as posts for supporting temporary structures.

The local plants including bamboos, palms, and perennial tree species are invaluable in making various handicraft, utensils, for various purposes. The degree of use of such biocultural resources is determined by the factors such as ethnicity, economic status, ethical level, variability in ecological system and types of art and skill possessed by a particular community. The use of various traditional plant technologies is higher in remote area with traditional socio-ecological systems than in area with transitional system as suggested by the elderly people and Gaon buras of Nyishi community. It was recorded that higher cultural attachment towards a particular plant technology leads to greater degree of use in present study. In present study, the effect of higher degree of cultural attachment and use level are observed to be higher towards degree of conservation of plant biodiversity. Furthermore, the cultural erosion and loss related to plant technology among younger generations as happening in transitional socio-ecological system has been recorded in the present study. Hence, this is the potential time to harness these culturally rich resources and conserve them with the bottom-up approach provided they are economically and socio-politically empowered. This can be achieved by taking the help of formal institutions, marketing and economic institutions, who value and commercialize the products and secure the intellectual property of traditional communities. The entire approach adopted in integrated manner will help in conserving biocultural resources used in traditional plant technology.

Documentation of ethnobotanical information

In present study, ethnobotanical data on 39 plant species belonging to 22 families were recorded. Information regarding their botanical name, family, common name, local name, and their ethnobotanical uses are presented in Tables 1, 2, and 3 The largest number of species were recorded from family Asteraceae (5 spp.), followed by Solanaceae (4 spp.), Poaceae (4 spp.), Urticaceae (3 spp.), Ranunculaceae (2 spp.), Brassicaceae (2 spp.), Lamiaceae (2 spp.), Zingiberaceae (2 spp.), Arecaceae (2 spp.) and rest of the family represented with one species each (Figures 3 and 4). ANOVA showed that family wise distribution of ethnomedicinal plants showed significant different ($P < 0.05$) among all the deras (local term for community shelter) of Nyishi.

As many as 28 species are used for medicinal purposes (49%) followed by 18 species of vegetable yielding or edible plants (27%), 9 species used as plant-based tools (16%), 2 plant species used as poisons (4%) and 2 species of sacred plants (4%) (Figure 3).

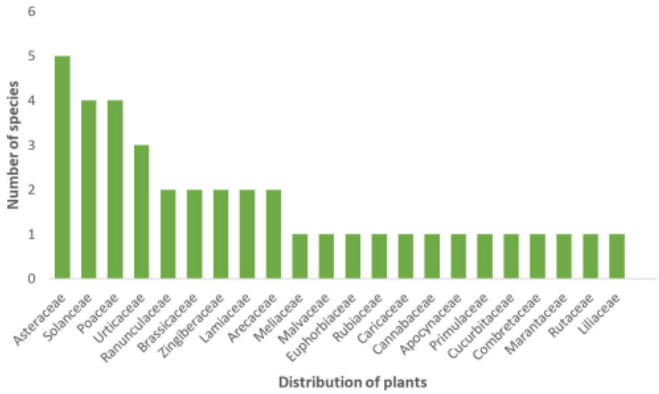

Figure 3. Family-wise distribution of plant species used by Nyishi tribe in Lower Subansiri District, Arunachal Pradesh

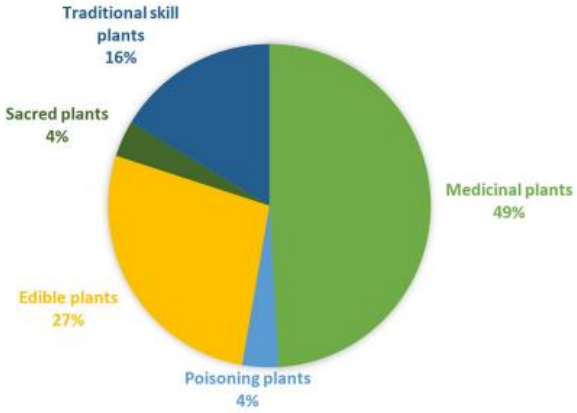

Figure 4. Ethnobotanical uses of the plants by Nyishi tribe in Lower Subansiri District, Arunachal Pradesh

Table 2. Total number of wild plants and their parts used in different ailments/problems

Category of ailments	No. of taxa	Plant parts used
Diarrhea and dysentery	3	Stem, fruit
Skin disease	3	Leaves, rhizome, bark, fruit
Healing cut and wounds	3	Leaves, oil
Cold and cough	4	Bulb, whole plant, leaves, fruits
Stomach problems	1	Whole plant, roots, fruits, leaves
Other liver problems	3	Fruits, stem, leaves, bark, seeds
Tooth problems	1	Leaves, flower, fruit
Dengue	1	Fruit
Muscle, abdominal pain and swelling	2	Whole plant
Piles	1	Bark, fruit
Asthma	1	Leaves
Snake, scorpion bite	1	Leaves
Insect repellent	1	Leaves
Ringworms	1	Leaves

The finding of this study suggests that Nyishi tribe are good in ethnomedicinal practices. Some notable plants used in preparation of herbal medicines are *Abroma augustum* (L.) L.fil., *Ageratum conyzoides* L., *Carica papaya* L., *Leucas indica* (L.) R.Br., 1811, *Pouzolzia bennettiana, Solanum nigrum* L., *Coptis teeta* Wall., *Saccharum officinarum* L., *Spilanthes paniculata* Jacq. ex S.S.Renner, Balslev & Holm-Niels., and *Zanthoxylum oxyphyllum* Edgew. for curing various common ailments such as dysentery, fever, anemia, cancer, snake bite, dengue, cough, cold, toothache, jaundice, asthma, and eye problems etc., and some of the plants used either singly or in combined form for an ailments or different ailments. The rhizome of *C. teeta* is very famous in traditional medicine to treat cough, cold, digestive system, inflammatory, eye problems and skin disorders. It regulates blood pressure and also helpful in anti-tumor and antibacterial activities. It is a rare and endangered plant species and also endemic to Arunachal Pradesh.

Nyishi people use different parts of the plant species for various ailments. It was recorded from our study that leaves were the most common used plant part followed by fruits, flowers, roots, whole plants, rhizomes, bark and bulbs. In some cases, their folk medicine preparation techniques generally start with the chanting of sacred mantra. Furthermore, it was also revealed that Nyishi community has a very interesting way of treating different diseases.

The Nyishi not only use the plants to cure diseases but also uses as food, firewood, wild edible fruit and vegetable. Some of the notable medicinal plants consumed by the Nyishi people as a main staple food besides its medicinal importance are *S. nigrum, B. vulgaris, Allium hookeri* Thwaites, *Pouzolzia bennettiana, Brassica campestris* Hegetschw., 1839, *S. paniculata* and *Raphanus sativus* L., *B. vulgaris* and *S. nigrum* are commonly used in curry and considered to be the main food of Nyishi people. The mature stem of *B. vulgaris* is used in building houses, bridges, furniture etc., and *Thaumatococcus daniellii* (Benn.) Benth. ex Eichler are also used in packing food materials by tribal people. Bark of *Nauclea orientalis* (L.) L. are used by the Nyishi community as fish poison for catching fish, i.e., the active ingredients are released by macerating the plant parts with the help of wooden stick or hammer, and then introduced into the water environment. While the roots of *A. ferox* Wall are crushed into paste, which is then caped in the metallic head of arrow, used for hunting large animals. Fishing and hunting are an important part of socio-cultural life of indigenous Nyishis. In earlier days, there was custom of community hunting. Nowadays, there is lots of concern about preserving wildlife in the studied area.

The traditional consumption of a variety of alcoholic beverages has been happening since time immemorial and is still an integral part of ethnic communities in the northeastern region of India. Popular traditional beer, locally known as *pona*, is prepared from rice (*Oryza sativa* L.). Pona has traditionally been used and served in all festive occasions like *Nyokum*, *Lungte*, birth and marriage ceremonies. During the present study, the young leaves and twigs of *Solanum lasiocarpum* Dunal were used as growth supplements in the preparation of fermentation starter as common cultures containing brewer's yeast (locally called *opap*).

Discussion

The Himalayan region is well known for its biodiversity and cultural mosaic. However, due to anthropogenic activities, including deforestation, functioning ecosystems have been degraded, leading to continuous soil loss (Akash and Navneet 2020a,b). This condition has intensified in recent years with growing demand for agricultural land and forest products, converting vast forest areas into plains and reducing forest nutrient dynamics. Therefore, it is essential to generate alternative income sources to support livelihoods and sustainability (Akash and Bhandari 2018; Akash and Navneet 2018; Akash et al. 2018, 2019; Akash and Zakir 2020). The Himalaya is also rich in medicinal plants (Dhar et al. 2002). Modern chemical medicine is costly and often causes side effects compared to traditional systems. Local communities living near forests continue to rely on ethnomedicinal plants for treating diseases due to their affordability, effectiveness, and lack of side effects (Negi et al. 2011).

Due to the modernization, the traditional skills and technologies which sustained the livelihood among the communities residing in rural areas has declined in last few years. It was observed in the present study that ornaments, headgear, belts, combs, baskets, smoking pipes, mats, fishing and hunting tools, storage items, kitchen utensils, and food systems are still available among the Nyishis. They totally depend upon the plant-based technologies in their day-to-day life, exclusively for constructing their dwellings, utensils, furniture, weapons such as bows and arrows, spears, armor, and implements like hunting and fishing traps, and even in constructing their houses.

The Nyishi tribes are considered good engineers and are experts in building long suspension bridges made of cane and bamboo over the rivers. The mature stem of *B. vulgaris* and *D. hookeri* are used in building houses, bridges and furniture. *Thaumatococcus daniellii* is also used in packing food materials by tribal people. Modernization and cultural erosion among younger generation have affected the dynamics of traditional knowledge and use of plant technology in life support system of Nyishi tribes. Majority of Nyishi community of transitional socio-ecological systems have medium degree of cultural attachment with their traditional plant-based technology. It was observed from the different studies that wild and edible plants provide extensive support to the local communities.

The study by Gao et al. (2024) revealed that traditional knowledge is exceeded by illiterate people as compared to the modern and it was also higher in men as compared to women. It is also noted that there is no such relation of knowledge of ethnomedicinal plants and level of education (Yaro 2018) but in the study of Dassou et al. (2024) recorded that traditionally women are not livestock owners or they don't have much knowledge as compared to men. Various studies have focused on diverse range of edible plants by indigenous groups in comparable with the current study results (Namsa et al. 2011; Showkat and Akhtar 2018; Gairola et al. 2021). Most of the folk healers are from old age who are strongly linked with their indigenous system of medicine (Tripathy et al. 2017).

Table 3. List of plant species with their ethnomedicinal uses and traditional skills to sustain the livelihood of Nyishi tribe, Arunachal Pradesh, India

Botanical name	Family	Common name	Local name	Collector no. assigned	Habit	Uses/ earlier literature
Abroma augustum (L.) L.fil.	Malvaceae	Devil's cotton	Ulat kombol	NY-1	S	Root juice is used to increase appetite whereas stem bark is used in dysentery / NA
Aconitum ferox Wall. ex Ser.	Ranunculaceae	Indian Aconite	Omi	NY-2	H	Roots are preparing hunting used poison large animals / NA
Ageratum conyzoides L.	Asteraceae	Chickweed	Paspai	NY-3	H	Leaves are used as insecticide and nematicide / (Gaur 1999; Akash et al. 2020b, 2021)
Allium hookeri Thwaites	Liliaceae	Hooker chives	Nyishi talap	NY-4	H	Bulb is used in cough and cold problem and also consumed as vegetables / NA
Azadirachta indica A.Juss.	Meliaceae	Neem	Neem	NY-5	T	All parts of this plant are used in skin infections, dental problems / NA
Bambusa vulgaris Schrad. ex J.C.Wendl.	Poaceae	Dibang bamboo	Tabih	NY-6	S	The mature stems are used in construction of house bridges, furniture and for kitchen utensils. Young shoots are edible / NA
Brassica campestris Hegetschw., 1839	Brassicaceae	Mustard	Honyir	NY-7	H	Leaves are used in food and oil is extracted from the seed / (Kadel and Jain 2008; Semwal et al. 2010; Akash et al. 2020b, 2021)
Calamus rotang L.	Arecaceae	Rattancane	Osho sanh	NY-8	S	The cane is used in making various household, furniture, handicrafts, also used for making headgear / NA
Cannabis sativa L.	Cannabaceae	Marijuana	Bhang	NY-9	H	Paste of leaves is used to against ringworms / NA
Carica papaya L.	Caricaceae	Papaya	Papita	NY-10	S	Fruits are consumed and young leaves are used to cure dengue / (Akash et al. 2020b)
Coptis teeta Wall.	Ranunculaceae	Mamoera	Tahiyo	NY-11	H	Rhizome is used in digestive system and also as anti- inflammatory and skin disorders / NA
Curcuma amada Roxb.	Zingiberaceae	Mango gmger	Takih	NY-12	H	Rhizome is used to treat liver disorder, sore throat and also used as spices / NA
Dendrocalamus hookeri Munro	Poaceae	Bhutan green Bamboo	Tabih	NY-13	S	Bamboos are used in house construction and young bamboo shoots are consumed as vegetables / NA
Elatostema platyphyllum Wedd.	Urticaceae	Elatostema	Hoj	NY-14	S	Roots are used to induce inflammation and vomiting / NA
Embelia ribes Burm.fil.	Primulaceae	Falseblack pepper	Vidang	NY-15	S	Fruits are used to treat liver disorder, liver worm infection / NA
Emilia sonchifolia (L.) DC. ex Wight	Asteraceae	Tassel flower	Genta	NY-16	H	Leaves juice is used against eye inflammation and also consumed as salad / NA
Chromolaena odorata (L.) R.M.King & H.Rob.	Asteraceae	Bitterbush	Puuhm	NY-17	H	Paste of leaves is used in treatment of wounds, skin infections, inflammation, insect repellents / (Akash et al. 2020b)
Holarrhena pubescens (Buch.-Ham.) Wall. ex G.Don	Apocynaceae	Kurchi	Kutaja	NY-18	T	Bark, fruits are used to treat dysentery. It is also used in colic, dyspepsia, piles, diseases of the skin and spleen / (Singh and Rawat 2011)
Zingiber officinale Roscoe	Zingiberaceae	Ginger	Takih	NY-19		Rhizome is used for stomach upset, motion sickness, nausea, vomiting and is edible / NA
Lagenaria siceraria (Molina) Standl.	Cucurbitaceae	Wild bottle guard	Upum	NY-20	C	Fruit is used for making utensils for storage, carrying liquids and for filtering the kala apong (alcohol) and also edible / NA
Laportea crenulata (Gaudich.) Chew	Urticaeae	Elephant nettle	Pospoi	NY-21	S	Young shoots are used in gastric problems / NA
Leucas indica (L.) R.Br., 1811	Lamiaceae	Thumba	Guma	NY-22	H	Whole plant is used in coughs, cold, abdominal pain and also to treat snake bites / NA

Livistona jenkinsiana Griff.	Arecaceae	Fanpalm	Toko patta	NY-23	T	Leaves are used for making coarse broom and also used in nursery as overhead shade. Whole plant is used as an ornamental and avenue plant, while fibrous sheaths are used in making ropes and various utensils and ornaments. It is also consumed as chutney / NA
Mikania scandens (L.) Willd.	Asteraceae	Climbing hempweed	Terhi	NY-24	C	Leaves are used in treating loose motion, paste used in cuts and wound / NA
Nauclea orientalis (L.) L.	Rubiaceae	Burtree	Tom	NY-25	T	Bark of the tree is crushed and used in fish catching as poison / NA
Ocimum tenuiflorum L.	Lamiaceae	HolyBasil	Tulsi	NY-26	H	Seed powder and leaves are used in cough and cold. Plant is also used in worship (Akash et al. 2020b, 2021)
Oryza sativa L.	Poaceae	Rice	Chawal	NY-27	H	Consumed as a staple food and used for making beer by fermentation.
Physalis minima L.	Solanaceae	Bladder cherry	Bayam	NY-28	H	The fruit is used as appetizer, bitter, diuretic, laxative and tonic / NA
Pouzolzia bennettiana Wight	Urticaceae	Hirta	Oyik	NY-29	S	Leaves are used to remove constipation and also edible / NA
Raphanus sativus L.	Brassicaceae	Radish	Mulla	NY-30	H	Roots and stem used as anthelmintic. Leaves are used to treat cholera, dysentery and also edible / NA
Ricinus communis L.	Euphorbiaceae	Cator oil plant	Rok plant	NY-31	S	Fruits and leaves are used to cure rheumatism, worm infection and in constipation as well as in abdominal problems / NA
Saccharum officinarum L.	Poaceae	Sugarcane	Taab	NY-32	H	Raw cullum is used in jaundice treatment and are also edible / NA
Solanum indicum Dunal	Solanaceae	African egg plant	Kacha byak	NY-33	H	The twig is used to ferment rice and millet and preparation of local beverage *apong* and *pona*. Fruit as Chutney / NA
Solanum nigrum L.	Solanceae	Kala Dhatura	Roor	NY-34	H	Its leaves are used to treat pneumonia, toothache and also used in stomach pain and consumed as vegetables / NA
Solanum khasianum C.B.Clarke	Solanaceae	Dutch egg plant	Taah byak	NY-35	S	Paste of fried fruit is used to treat dental pain / NA
Spilanthes paniculata Jacq. ex S.S.Renner, Balslev & Holm-Niels.	Asteraceae	Tootache plant	Mersha	NY-36	H	Flower is used to treat toothache and leaves are consumed as salad / NA
Terminalia microcarpa Decne.	Combretaceae	Rollock	Rollock	NY-37	T	Wood is used in making local grinder and various house hold tools / NA
Thaumatococcus daniellii (Benn.) Benth. ex Eichler	Marantaceae	Sweet prayer plant	Ook	NY-38	H	Leaf is used in making local plate, dish, and paste of leaves is used as antidote against venoms, sedative, diabetes / NA
Zanthoxylum oxyphyllum Edgew.	Rutaceae	Pricklyash	Honam	NY-39	S	Leaves can be used as carminative, depurative, treating rheumatism, asthma, dyspepsia / NA

Note: NY: Nyishi tribe, H: Herb, S: Shrub, T: Tree, C: Climber, NA: Not applicable; we didn't find the same ethnomedicinal uses which we have recorded

The huge biodiversity of medicinal wealth in Himalayan region (Dhar et al. 2002) has great advantages for the local communities. Despite being great advancement in medical science, local communities still used plant-based products for sustainability and livelihood due to their effectiveness and availability (Semwal et al. 2010). During the present study, ethnobotanical data on 39 plant species belonging to 22 families were collected. The present study favor the results from other studies in which Asteraceae, Rosaceae and Polygonaceae were the dominant family from Kashmir Himalaya (Abdullah and Andrabi 2021) but incomparable with the study from Kashmir Himalaya in which Asteraceae, Lamiaceae, and Ranunculaceae were most dominant family. In the present study, Asteraceae was the most dominant family of medicinal plants, which is comparable with the study of Saklani and Jain (1994). Similar findings were also documented by Tripathy et al. (2017), while studying the ethnomedicinal plants of Papum Pare district.

The knowledge of traditional knowledge is of great concern, and it has been lost generation after generation. There are various factors responsible for the erosion of indigenous knowledge including poverty and modernization. Different methods of medicinal application including infusions, decoction, powder, and juices were described in studies (Bhatia et al. 2015). The tribes use these forms with honey, milk, and with boiled water to treat fever, cold and

cough as well as other human ailments. Many of the earlier studies confirmed decoction and maceration as important and primarily mode of utilization of medicinal plants (Dougnon et al. 2017; Ouachinou et al. 2017; Busari et al. 2021). The high use of bark parts could be due to its effectiveness against pathogens. According to our study, most folk healers use leaves followed by fruits, flowers, roots, whole plants, rhizomes, bark and bulbs etc. The traditional ecological practices of the Nyishi tribe—particularly their use of bamboo, cane, and other forest resources for crafting tools, utensils, and ornaments—demonstrate a deep integration of environmental knowledge and cultural expression. When compared with neighboring tribes such as the Apatani, Monpa, and Adi, the Nyishi exhibit a more craft-based, utilitarian approach to plant use, especially evident in their male-dominated production of hunting tools, storage containers, and household items. In contrast, the Apatani practice highly structured terrace-based agriculture with integrated fish farming, which reflects a sophisticated system of landscape-level sustainability. The Monpa and Adi communities further differ by embedding conservation within their belief systems and ritual practices, using sacred groves and taboos to regulate resource use. While the Nyishi rely on oral knowledge transmission and hands-on learning within households, this system is increasingly at risk due to modernization and declining intergenerational interest. However, the strong cultural attachment to specific tools and plants among the Nyishi also presents an opportunity: by integrating conservation-oriented knowledge from neighboring tribes and reinforcing local practices through education and policy support, the Nyishi community could revitalize their traditional ecological knowledge systems while ensuring sustainable resource use for future generations. A comparative analysis between the present study on the Nyishi tribe and earlier ethnobotanical research on the Apatani and Adi communities of Arunachal Pradesh reveals both convergence and divergence in indigenous knowledge systems. While the Nyishi exhibit rich plant-based craftsmanship—crafting a wide range of traditional tools, utensils, and traps primarily from bamboo, cane, and wood—the emphasis remains on functional utility, with ecological knowledge passed down through oral traditions and hands-on experience, especially among male members. In contrast, studies on the Apatani tribe (e.g., Kala 2005; Dollo et al. 2009) highlight a more systematic and gender-inclusive transmission of ecological knowledge, particularly in agricultural practices and ethnomedicine.

In recent years, continuous unsustainable exploitation, habitat degradation, anthropogenic pressure and change in climatic conditions had led to rapid depletion of several plant species. Moreover, traditional skills and medicinal knowledge is also depleting day by day because of change in socio-cultural dynamics, migration from villages to urban areas, lack of interest of youths on traditional values and dependency on modern technologies and healthcare facilities in the region. Hence, documentation of available ethnobotanical plant species and traditional indigenous knowledge is urgently required. The Government of India through Department of Science and Technology (DST) is trying to accelerate various aspects of bio-cultural knowledge and plant technology in Arunachal Pradesh. However, such noble initiative would bear much fruits if private land owners and community are engaged in the management of wild species used in making traditional technology. There is an urgent need to value, restore, collect and utilize this native technology of the Nyishi tribe. These technologies can be marketed with the help of information technology, NGOs, formal organizations like North-East Council, for example by promoting bamboo technology center. Furthermore, the rich heritage of arts, crafts and plan technological knowledge of Arunachal Pradesh is sure to add color to cultural heritage of the country.

In conclusion, the communities residing in the Northeastern Himalaya region use plants as a source of medicine and food for their livelihoods and primary health needs. In a few areas, people abandon the traditional knowledge because of urbanization but in recent past it has been observed that communities are more attracted to the traditional medicine system. Folk knowledge has passed from one generation to another generation in this region due to their cultural value but more attention is needed for the conservation and documentation of traditional knowledge as it is less scripted on paper and depends on the people's practices and experiences. Considering the ethnomedicinal and traditional knowledge on species, we recommend preparing various conservation management plans for threatened and endangered species. Thus, the present study clearly demonstrated that apart from many conventionally methods of using ethnomedicinal plants, traditional skills on utilizing plant - based products from the study site are similarly important in multidimensional ways. Furthermore, the policies viz. institutionalizing community-led documentation, conservation programs can empower the Nyishi people to safeguard and transmit their traditional knowledge while connecting it to livelihood opportunities such as eco-tourism, handicrafts marketing, and sustainable agriculture. Additionally, other policy such as integrating indigenous knowledge systems into regional biodiversity management plans will ensure that conservation efforts respect local cultural practices, promote sustainable resource use, and strengthen community resilience against environmental and socio-economic challenges.

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Traditional medicinal knowledge and use of *Ubar Kampung* among local healers in Tatar Sunda, West Java, Indonesia

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Abstract. *Febriyanti RM, Susilawati Y, Tjitraresmi A, Muhaimin. 2025. Traditional medicinal knowledge and use of* Ubar Kampung *among local healers in Tatar Sunda, West Java, Indonesia. Asian J Ethnobiol 8: 202-221.* In Sundanese communities (West Java, Indonesia), traditional medicine (*Ubar Kampung*) remains central to primary health care. This study aims to document medicinal plant use by local healers and quantify cultural salience-that is the significance of a plant in the cultural practices and beliefs of the Sundanese people. Studies were conducted between 2017 and 2019 using semi-structured interviews with 52 purposively selected key informants (healers, elders, traditional birth attendants) across five Sundanese villages. We recorded 111 species from 54 families. Leaves were the most frequently used part, and decoction was the predominant preparation. *Curcuma longa* and *Kaempferia galanga* had the highest RFC (1.00) and high UV (4.07 and 4.15). Digestive disorders showed the strongest agreement (ICF = 0.88), with *Psidium guajava* cited unanimously for diarrhea (FL = 100%). Musculoskeletal conditions also showed high consensus (ICF = 0.87), particularly for *K. galanga*. *Ubar Kampung* represents a resilient medical system, with culturally salient species that align with reported pharmacological activities. Prioritized taxa (such as *K. galanga, C. longa,* and *P. guajava*) warrant targeted pharmacological and conservation action. Documenting this knowledge supports sustainable use and culturally appropriate integration with regional health services and paves the way for future research and discoveries on plant knowledge and use among healers in the Tatar Sunda Region, West Java, Indonesia.

Keywords: Ethnobotany, informant consensus factor, relative frequency of citation, Sundanese traditional medicine, use value

Abbreviation: FC: Frequency of Citation, FL: Fidelity Level (percentage agreement on a species' principal use), ICF: Informant Consensus Factor, NUR: Number of Use Reports (the total number of citations for an ailment category), PROSEA: Plant Resources of Southeast Asia database, RFC: Relative Frequency of Citation, UV: Use Value

INTRODUCTION

Over the past decades, ethnobotany and ethnomedicine have gained prominence as interdisciplinary approaches to drug discovery, underpinning the development of numerous therapeutic agents (Hu et al. 2020; Manzoor et al. 2023). Approximately 75% of herb-based remedies and therapeutics used globally have their origins in traditional medicine, with numerous synthetic analogs developed from plant-derived compounds. Notable examples include colchicine (*Colchicum autumnale* L.), paclitaxel (*Taxus brevifolia* Nutt.), artemisinin (*Artemisia annua* L.), silymarin (*Silybum marianum* (L.) Gaertn.), and vincristine and vinblastine (*Catharanthus roseus* (L.) G.Don) (Choudhury et al. 2020; Ralte et al. 2024).

Studies have highlighted the role of traditional medical knowledge in ethnopharmacological research, particularly in understanding plant efficacy within cultural contexts, preserving community health knowledge, and ensuring the sustainability of these practices (Baharvand-Ahmadi et al. 2016; Mahapatra et al. 2019; Gyeltshen et al. 2024). In many societies, medicinal knowledge is maintained by village elders or traditional healers who pass it down through oral tradition or ritual practice (Tamalene et al. 2016; Fathir et al. 2021). Despite its importance, local ethnobotanical traditions, including the use of specific plant species, are increasingly at risk of extinction in numerous regions worldwide. The erosion of cultural transmission to younger generations is causing an irreversible loss of ethnobotanical wisdom, creating an urgent need for documentation and scientific validation before this knowledge disappears (Hu et al. 2020; Febriyanti 2021; Manzoor et al. 2023).

Indonesia, with its rich cultural diversity and biodiversity, is home to approximately 30,000 plant species, of which only 940 are recognized for their medicinal properties, and just 300 are used in herbal industries (Putri et al. 2016; Rahayu et al. 2024a). Variations in environmental conditions, cultural beliefs, and customary practices across Indonesia contribute to diverse traditional medicinal knowledge among its many ethnic groups. For instance, an ethnomedicine study in Lombok, West Nusa Tenggara, emphasizes how palm-leaf manuscripts (*lontar*), particularly of those on the Usada, guide traditional healers by providing detailed information about diseases, treatments, herbal remedies, and incantations. Currently, around 40 million Indonesians utilize approximately 6,000 plant species for healthcare, underscoring the importance of traditional medicinal practices nationwide (Elfahmi et al. 2014).

Nationwide studies on traditional medicinal plant knowledge, called RISTOJA (research on medicinal plants and jamu) in

2015 and 2017, have demonstrated the richness and diversity of traditional practices among Indonesia's indigenous communities (Ministry of Health of the Republic of Indonesia 2017). However, their findings also underscore a critical limitation: the need for targeted, region-specific studies to capture the nuanced practices of individual communities. As highlighted in the nationwide findings, there is an urgent need for region-specific studies to complement national-level surveys, ensuring that localized practices are properly documented and preserved.

The Sunda Region of West Java in Indonesia demonstrates the potential for ethnobotanical research. This area is well known for its cultural heritage and diverse plant life, making it an important source of traditional medicinal knowledge. It provides a strong case for a detailed ethnobotanical study for three main reasons: firstly, its mountainous terrain supports a unique and varied collection of plants, increasing the chances of discovering species with special pharmacological properties, secondly, the Sundanese community has inhabited the area for generations, fostering a deep and resilient body of local ecological knowledge, thirdly, their traditional healing practice, known as *Ubar Kampung*, remains an integral part of community healthcare, particularly in rural areas. Yet, it has not been subjected to large-scale documentation or scientific validation (Heinrich 2000; Balick and Cox 2020).

Sundanese traditional medical practice is called *Ubar Kampung*, a practice that remains widely used, especially in rural areas. Research has shown that many medicinal plants used in *Ubar Kampung* align with modern scientific literature, highlighting the potential to incorporate traditional knowledge into current healthcare systems (Rahayu et al. 2020; Dewi et al. 2023; Febriyanti et al. 2024). Our previous study has examined qualitative and quantitatively the knowledge dimension of *Ubar Kampung*, including transmission pathways and sociocultural drivers (Febriyanti 2021). Building on that foundation, the present study focuses on the documentation and quantitative appraisal of medicinal plants, specifically providing a species list and computing standard ethnobotanical indices including Relative Frequency of Citation (RFC), Use Value (UV), Fidelity Level (FL), and Informant Consensus Factor (ICF) to prioritize taxa for future ethnopharmacological validation and conservation.

MATERIALS AND METHODS

Study area

Java, the central island of Indonesia, holds a pivotal position not only geographically and administratively but also in terms of population density. With approximately 141 million residents, Java accounts for 56.7% of Indonesia's total population (Goro et al. 2024). Geographically and ethnographically, Java is traditionally divided into three regions: the western part, encompassing the national capital Jakarta, West Java Province, and Banten Province; Central Java, including the Special Region of Yogyakarta; and eastern Java, which also incorporates Madura Island (Ananta et al. 2015).

This study focused on the Tatar Sunda Region, home primarily to Sundanese communities. To date, there are only limited indigenous Sundanese communities in West Java. According to the data from the Department of Culture and Tourism, there are eight indigenous communities (*kampung*/village) in the Sunda Region, namely Kampung Cireundeu, Kampung Pulo, Kampung Naga, Kampung Dukuh, Kampung Gede Kasepuhan Cipta Mulya, Kampung Mahmud, Kampung Kuta, and Kampung Cikondang (Harashani 2018; Hernawati et al. 2022).

Fieldwork was carried out in five culturally significant Sundanese villages to document the indigenous knowledge and cultural practices of the local community. These villages included Kampung Naga, Kasepuhan Cipta Mulya, Kampung Dukuh, Kampung Cireundeu, and Kampung Pulo. These sites were selected for their cultural significance and their role in preserving Sundanese traditions (Figure 1). Detailed information on each location is presented in Table 1.

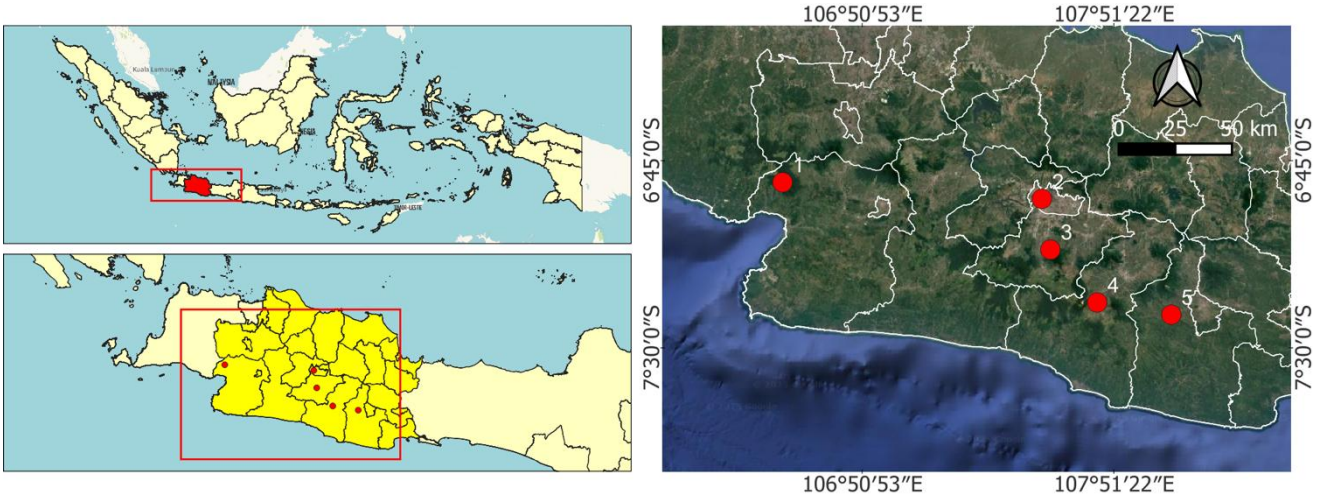

Figure 1. Study area: 1. Kasepuhan Cipta Mulya, 2. Kampung Cireundeu, 3. Kampung Dukuh, 4. Kampung Pulo, 5. Kampung Naga, in Tatar Sunda Region, West Java, Indonesia

Table 1. Key demographic and geographic details of fieldwork sites

Village	GPS coordinates	Altitude (masl)	Ecology
Kasepuhan Cipta Mulya	6°50'12"S, 06°31'45"E	~700	Hilly terrain; secondary forests; subsistence fields
Kampung Cireundeu	6°54'10"S, 07°34'02"E	~670	Agroforestry environment near urban fringe, hills with home gardens
Kampung Dukuh	7°06'21"S, 07°36'05"E	~800	Low montane area; dense bamboo groves; small-scale horticulture
Kampung Pulo	7°19'03"S, 07°47'19"E	~650	Near riverbanks with terraced rice fields, pockets of remnant natural forest
Kampung Naga	7°21'59"S, 08°05'08"E	~480	Valley ecosystem is surrounded by forests, paddy fields, strongly protected environment

Data collection

This study employs an ethnobotanical methodology to investigate indigenous medical knowledge, particularly focusing on the practice of *Ubar Kampung* as performed by local healers in the Sundanese community. The methodological framework integrates three principal perspectives: the historical perspective, the emic and etic perspectives, and the field ethnological study, ensuring a comprehensive understanding of the practice (Silva et al. 2014; Febriyanti 2021). An emic perspective emphasizes insider understanding of vernacular illness categories, explanatory models, and rationales for plant use, ensuring that descriptions remain true to local knowledge systems and practices. In contrast, an etic perspective uses analyst-driven concepts and standardized classifications to allow for cross-case comparisons, quantitative analysis, and hypothesis testing.

Historical perspective

The historical perspective examines the development of medical practices, beliefs, and health systems within the Sundanese community over time. This component of the study investigates how cultural, social, and historical factors have influenced the practice of *Ubar Kampung*.

Emic perspective

The emic perspective seeks to understand health and illness through the lens of local healers and community members (Pham et al. 2020). Data collection was conducted qualitatively between 2017 and 2019, employing in-depth interviews with 52 informants who were purposively selected from five traditional villages. Informants included elders, traditional healers, and community leaders, and *paraji* (traditional birth attendants), and aged between 55 and 71 years. It is important to acknowledge that the informant sample size was limited and not representative of the entire Sundanese population.

Therefore, quantitative generalizations cannot be reliably made. The key informants were specifically chosen for their extensive indigenous knowledge of medicinal plants, aligning with the study's aim of elucidating ethnobotanical practices. Prior to recruitment, permission and referrals were obtained through community leaders, ensuring cultural and ethical considerations were respected.

Interviews were conducted in Sundanese, later transcribed into English by the first author, a native Sundanese speaker who is fluent in both languages. Semi-structured interviews guided by specific questions elicited detailed information on the following aspects: local knowledge about *Ubar Kampung*; sources of information about the practice; perceptions of disease symptoms; and the identification, use, preparation, and processing of medicinal plants. This approach focuses on species most relevant to participants, as these are typically part of their active memory and cultural practices (Silva et al. 2014).

Field ethnological study

Field studies incorporated participant observation, informal conversations, and immersive interactions within the community. Researchers documented the practice of *Ubar Kampung* by observing daily life and traditional health practices. Key informants also accompanied researchers to their gardens, identifying plants used in *Ubar Kampung*. Photographs and in situ documentation ensured the accurate recording of medicinal flora.

Plant identification

Plant identification was conducted by comparing their morphological characteristics with references in authoritative sources such as Plant Resources of Southeast Asia (PROSEA) (https://prosea.prota4u.org) and other reputable botanical literature. Scientific nomenclature was validated and updated using the World Flora Online Plant List (https://www.worldfloraonline.org). A subset of 20 frequently cited antidiabetic species from the same informants had voucher specimens collected and archived (Febriyanti 2021). For the remaining taxa reported in the present study, photographs serve as documentary evidence to support identifications, with the recognition that photographs do not replace herbarium vouchers.

Data analysis and reporting

To present the ethnobotanical data, a mixed descriptive-quantitative approach was employed. Since a single index can only offer a finite amount of information, we used a wide range of indices to enable a comprehensive analysis of the data, including the Relative Frequency of Citation (RFC), Use Value (UV), the Fidelity Level (FL), and the Informant Consensus Factor (ICF) (Hoffman and Gallaher 2007).

Relative Frequency of Citation (RFC)

To evaluate the cultural and medicinal significance of individual plant species, the Relative Frequency of Citation (RFC) was calculated. This measure reflects the proportion of informants who cited a particular plant species and is derived by dividing the Frequency of Citation (FC) for a species by the total number of informants (N) surveyed. Higher values (closest to 1) indicate that a medicinal plant was cited consistently by informants for treating a specific

illness. In contrast, lower values reflect less frequent citation or less common therapeutic usage (Ralte et al. 2024).

Use Value

The Use Value (UV) was employed to quantify the relative significance of medicinal plants known in the study region (Hernawati et al. 2022). The UV for each species was determined using the formula:

$$UV = \frac{\Sigma Ui}{N}$$

where *N* is the total number of informants and Ui is the total number of uses reported by each informant for a given species. A higher UV denotes broader usage and knowledge of the plant within the community.

The Fidelity Level (FL)

Fidelity Level (FL) was calculated to measure the degree of consensus among informants regarding the use of a specific plant species for treating a particular ailment. This parameter was calculated using the following formula:

$$FL = \frac{Ip}{Iu}\ x\ 100\%$$

Here, I_p represents the number of informants who reported using a species for the same primary therapeutic purpose, and I_u is the total number of informants who mentioned the species for any use. The FL value expresses the percentage agreement among informants about the specific use of a plant.

Informant Consensus Factor (ICF)

The Informant Consensus Factor (ICF) quantified agreement among informants for each ailment category and was calculated as:

$$ICF = \frac{(NUR - Nt)}{(NUR - 1)}$$

Here, NUR is the total number of Use-Reports (URs) recorded for a given ailment category (i.e., the sum of URs across all ailments subsumed under that category and across all informants), and Nt is the number of distinct plant taxa cited for that category. ICF ranges from 0 (no consensus) to 1 (complete consensus), with higher values indicating that many URs converge on relatively few taxa.

All analyses were conducted at the species level unless stated otherwise. Summary statistics are reported as median (IQR) for skewed variables and mean (SD) otherwise. Two-sided tests with $\alpha = 0.05$ were used. The relationship between Relative Frequency of Citation (RFC) and Use Value (UV) across species was examined. Because RFC and UV were non-normally distributed (Shapiro–Wilk, $p < 0.001$), Spearman's rank correlation (ρ) was used as the primary analysis, with Pearson's r reported as a descriptive sensitivity estimate. Influential observations were assessed using standardized residuals ($|z| > 3$) from an ordinary least-squares fit. Correlation coefficients, two-sided p-values, and 95% confidence intervals were reported (Pearson via Fisher's z transformation; Spearman via bootstrap). All analyses were conducted in Python (SciPy/StatsModels, matplotlib).

Comparisons by plant family and ailment

To evaluate whether Use Value (UV) varies across plant lineages, species were grouped by family. Families with ≥ 3 species were retained for inference. A Kruskal–Wallis test assessed overall differences in UV among families. When the global test was significant, pairwise Mann–Whitney U tests were performed and Benjamini–Hochberg False-Discovery Rate (BH-FDR) adjustment was applied across pairwise *p*-values. For descriptive inference, family-level means, medians, SD, and bootstrap 95% CIs (B = 5,000) of UV were reported. Species-level category-specific UV distributions were compared across ailment categories using Kruskal–Wallis, followed by pairwise Mann–Whitney U tests with BH-FDR correction. Category were tabulated.

Family–category structure was examined using a contingency table of summed Use-Reports (UR) per plant family × ailment category. A chi-square test of independence assessed global association. Standardized Pearson residuals were used to identify over- or under-represented family–category pairs. Outputs include the UR matrix, expected frequencies, residuals, and a heatmap.

In the present study, transmission processes were not reported, as qualitative analyses of knowledge, beliefs, and practices within the *Ubar Kampung* system have been reported previously (Febriyanti 2021). Accordingly, the study was intentionally limited to the inventory of medicinal plants and their cultural salience (RFC, UV, FL, ICF), thereby providing a comparable baseline for prioritizing species for subsequent ethnopharmacological follow-up. Any discussion of knowledge erosion is provided as contextual background, not as findings derived from the current dataset.

RESULTS AND DISCUSSION

The Sundanese people: Cultures and communities

The Tatar Sunda, or Parahyangan region, encompasses the cultural areas of West Java and Banten, where the majority of inhabitants identify as Sundanese (Roosita et al. 2008; Hernawati et al. 2022). Due to its predominantly mountainous terrain, this region is also referred to as Parahyangan, derived from the Sanskrit term Hyang, meaning "god." Historical evidence suggests that the Sunda Region has existed for centuries; one of the earliest inscriptions referencing "Sunda" is the Shanghyang Tapak inscription, dated 952 Saka (1030 CE), discovered in Cibadak near Sukabumi. The name "Sunda" applies to the people, their language, and the historical kingdom located in the western part of Java (Roosita et al. 2008; Febriyanti et al. 2022).

As an ethnic group, the Sundanese are not only the second-largest ethnic group on Java but also in all of Indonesia. Sundanese culture is dominant in West Java and has spread to other parts of Indonesia, including the transmigration areas in Lampung Province on Sumatra. In the context of ancient beliefs, the Sundanese belief system holds that a balanced life can be achieved by a harmonious relationship with nature, gods/spirits, and human beings (Saefullah 2023). In their research, Gyasi et al. (2015) elucidated the belief paradigm, which emphasized the triadic

of natural forces: mind, soul, and body (Gyasi et al. 2015). The capability of traditional medicine in the holistic healing process, taking into account the importance of mind, body, and soul, is an important component in the health-seeking process. Specifically, Sundanese cosmology is grounded in a triadic concept, namely *tritangtu*, encompassing the individual, the spiritual realm, and the universal context. This philosophical framework is reflected in various aspects of Sundanese life, including healthcare, landscape usage, housing configurations, and ecological arrangements (Saefullah 2023).

Patterns in plant usage and dominant families

Our study documented 111 medicinal plant species, with Zingiberaceae, Asteraceae, Fabaceae, and Lamiaceae being the most represented families (Figure 2). Leaves were the primary plant part used, and decoction (boiling) was the predominant preparation method (Figures 3.A and 3.B). The complete species list, together with each taxon's Relative Frequency of Citation (RFC) and Use Value (UV), is provided in Table S1.

Association between RFC and UV. Across 111 species, Spearman's ρ = 0.817 (bootstrap 95% CI 0.712-0.892), indicating that more culturally salient taxa tend to be reported for a greater number of uses. Pearson's correlation was comparable (r = 0.884, 95% CI 0.836-0.919). The scatterplot with fitted line is provided in Figure 4.

Frequently used species and ethnomedicinal importance

Our analysis is further enriched by considering quantitative ethnobotanical indices such as Used Report (NUR), Fidelity Level (FL), and the Informant Consensus Factor (ICF) for various diseases (Table 2).

Table 2. Informant Consensus Factor (ICF), Fidelity Level (FL), and the most cited medicinal plants by ailment category

Ailment category	Disease/ailment under each category	No. of plants used (Nt)	Used reports (NUR)	ICF	Most cited plant	FL (%)	Purpose of the most cited plants
Infectious and Parasitic Diseases	Viral infections (dengue, malaria, hepatitis), bacterial infections, fungal infections, parasitic infestations	68	546	0.88	*Momordica charantia* L.	65	Dysentery, dengue fever
Cardiovascular and Circulatory Disorders	Diabetes mellitus, hypercholesterolemia/hyperlipidemia, obesity, and other metabolic syndromes.	101	662	0.85	*Apium graveolens* L.	100	Hypertension
Metabolic and endocrine disorders	Hypertension (essential or secondary), heart disease, circulatory problems (e.g., varicose veins, edema if primarily cardiovascular in origin).	94	700	0.87	*Swietenia mahagoni* L. Jacq	100	Diabetes
Musculoskeletal and Connective Tissue Disorders	Rheumatism (e.g., rheumatoid arthritis), osteoarthritis, gout, low back pain, muscle pain, sprains/strains.	76	599	0.87	*Kaempferia galanga* L.	100	Rheumatism
Digestive and Gastrointestinal Disorders	Diarrhea, constipation, ulcers (peptic/gastric), gastritis, indigestion/dyspepsia, hemorrhoids, dysentery.	111	939	0.88	*Psidium guajava* L.	100	Diarrhea
Respiratory Disorders	Asthma, bronchitis, cough (when it reflects a respiratory condition), common cold, and other respiratory infections.	89	611	0.86	*Cymbopogon citratus* (DC.) Stapf	100	Cough and sore throat
Dermatological Disorders and Wound Care	Burns, dermatitis/eczema, psoriasis, acne, wound healing, skin ulcers, and sunburn.	93	572	0.84	*Ageratum conyzoides* L.	100	Wound healing
Genitourinary	Kidney disorders (stones, chronic kidney disease), urinary tract infections	60	354	0.83	*Sonchus arvensis* L.	100	Urinary tract infection
Oncological (Cancers)	Any reference to malignant neoplasms, cancer prevention, or anticancer claims.	8	12	0.36	*Acmella paniculata* (Wall. ex DC.) R.K.Jansen	19	Anticancer
Neurological & Mental Health	Headache/migraine, anxiety, stress-related complaints.	33	190	0.83	*Cymbopogon citratus* (DC.) Stapf	88	Insomnia
Nutritional Disorders	Anemia and other malnutrition.	42	200	0.79	*Curcuma xanthorrhiza* Roxb.	88	Apetite enhancer
Symptomatic condition	Fever, headache, nosebleed.	72	341	0.79	*Sandoricum koetjape* Merr.	46	Fever
Women reproductive health	Menstrual disorders (dysmenorrhea, irregular cycles), postpartum issues, and lactation support.	50	297	0.83	*Sauropus androgynus* (L.) Merr.	100	Enhance breastmilk production
Tooth and mouth disorders	Mouth ulcers, swelling gums, and toothache.	34	125	0.73	*Areca catechu* L.	50	Swollen gum, toothache

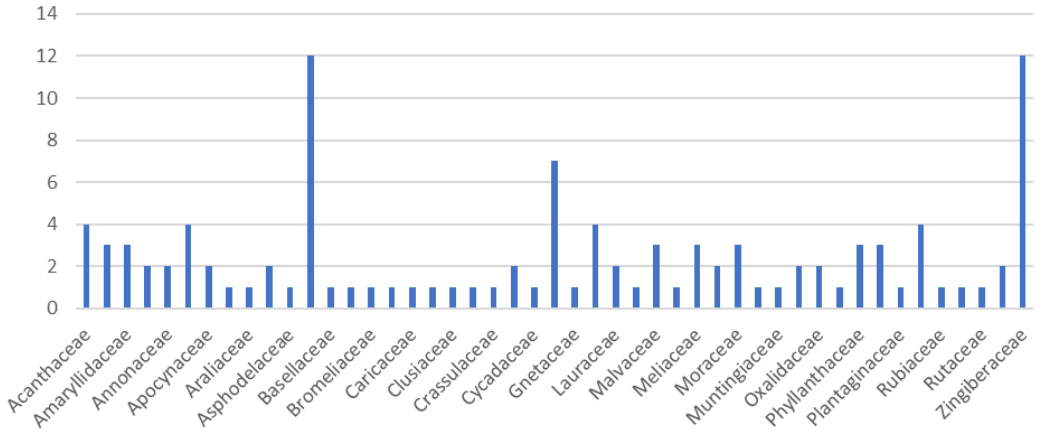

Figure 2. Frequency distribution of plant families used in *Ubar Kampung*

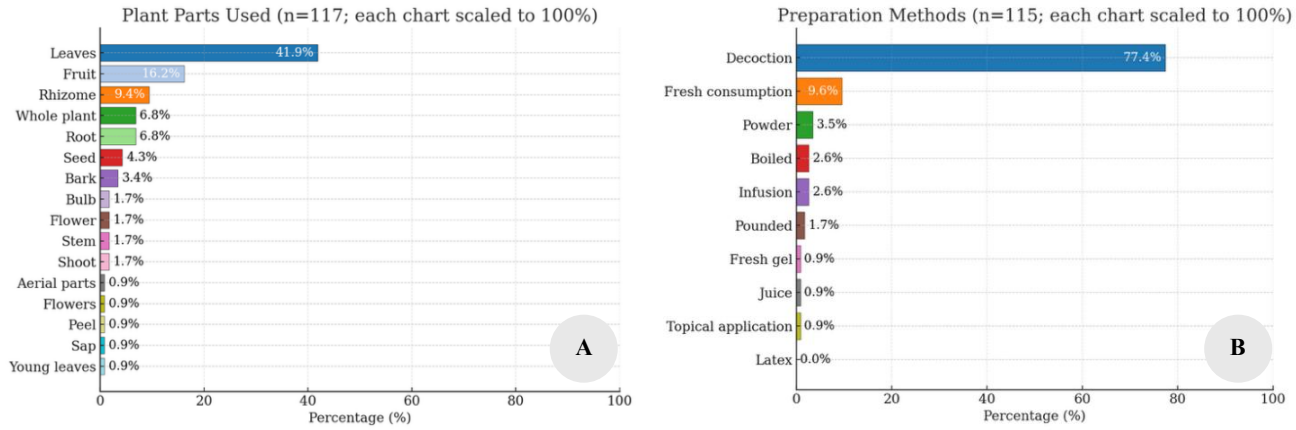

Figure 3. A. Part used of medicinal plants, B. Preparation methods of medicinal plants used

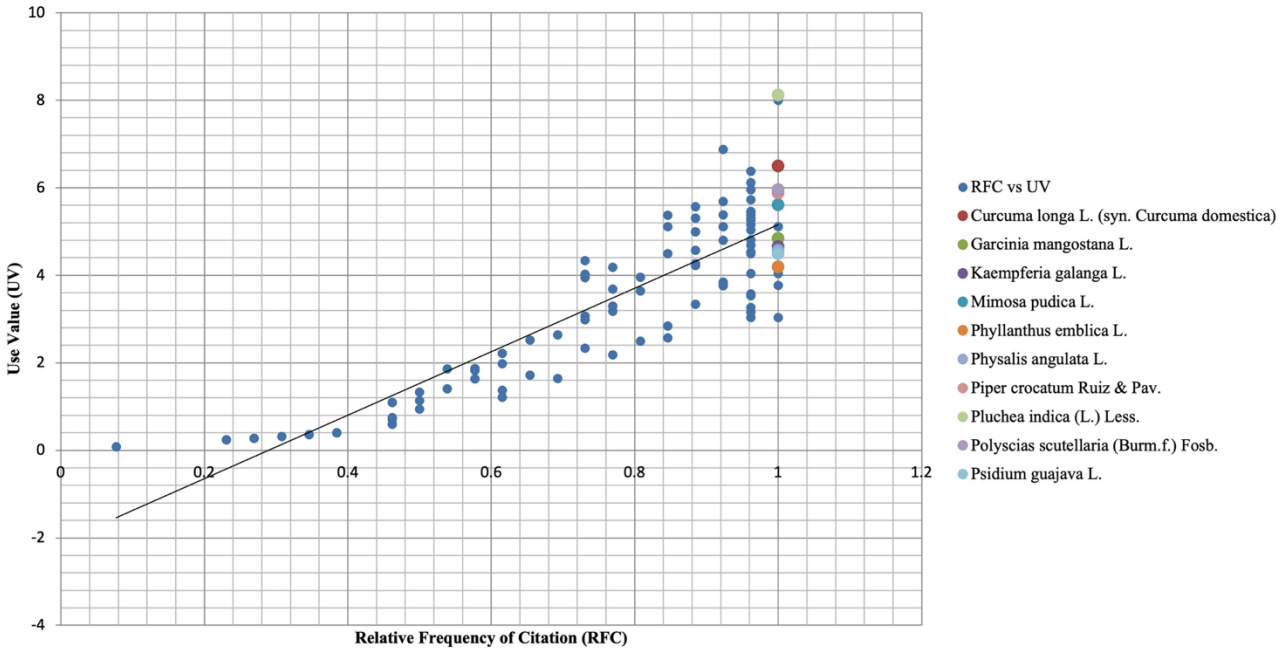

Figure 4. Scatter plot of Relative Frequency Citation and Use Value with top 10 highest Use Value

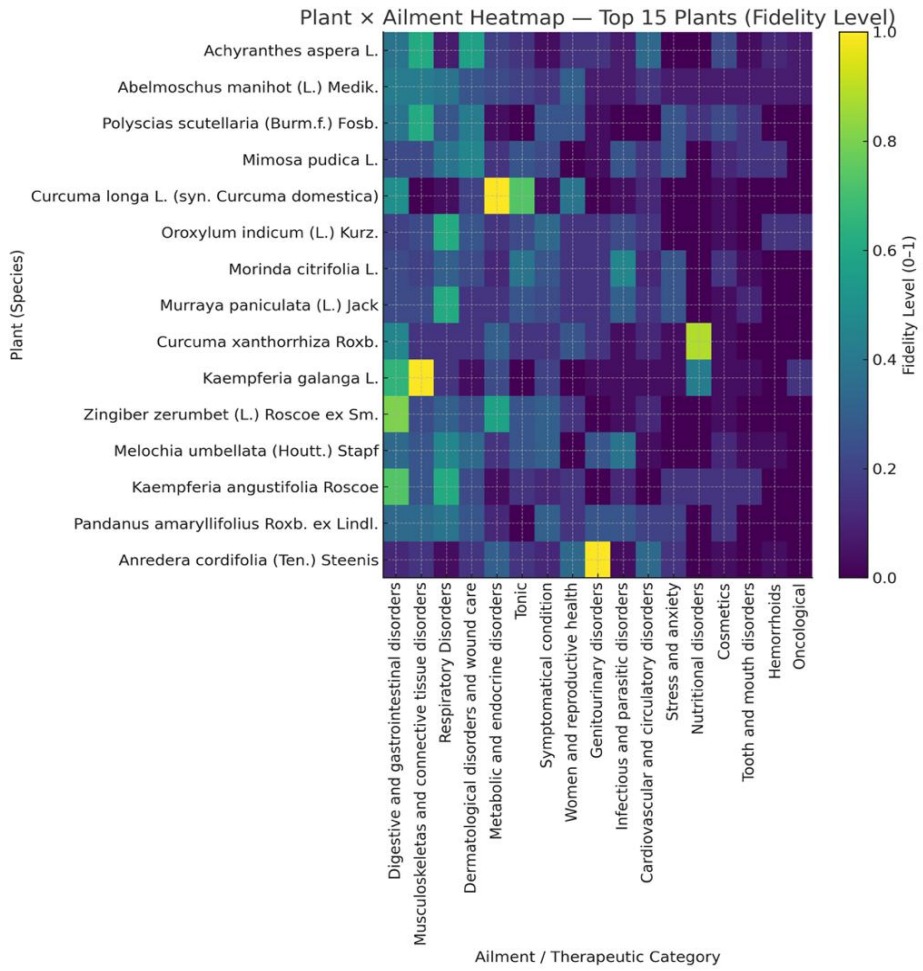

Figure 5. Heatmap of 15 plants with highest Fidelity Level in each therapeutic category

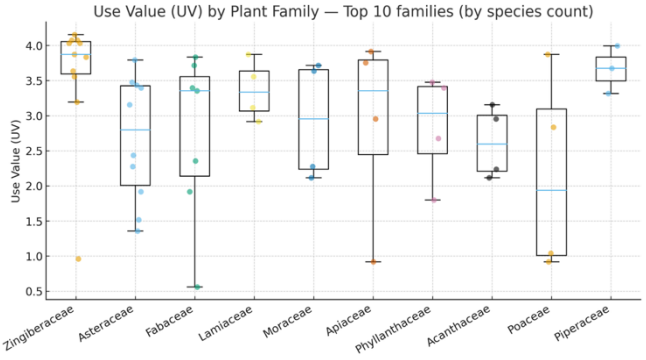

Figure 6. Use Value (UV) by plant family. Boxplots show species-level UV for the top 10 families (by species count); points are individual species. Families differ significantly (Kruskal–Wallis; pairwise BH-adjusted Mann–Whitney in the Supplementary File S2)

High informant consensus was observed for Infectious and Parasitic (ICF = 0.88; Nt = 68; NUR = 546), Digestive and Gastrointestinal (ICF = 0.88; Nt = 111; NUR = 939), Metabolic and Endocrine (ICF = 0.87; Nt = 94; NUR = 700), and Musculoskeletal disorders (ICF = 0.87; Nt = 76; NUR = 599). High ICF coupled with large NUR indicates strong agreement on what is used for common, high-burden complaints, and suggests robust household-level repertoires with multiple options (large Nt) for first-line care. Respiratory (ICF = 0.86; Nt = 89; NUR = 611) and Cardiovascular and Circulatory disorders (ICF = 0.85; Nt = 101; NUR = 662) similarly show high consensus, consistent with frequently managed conditions in primary/community settings. Top 15 plants with highest Fidelity Level are visualized in Figure 5.

Use Values (UV) were compared across plant families with ≥3 species. A significant overall difference was detected. Families with the highest central tendency were observed to include those with multiple culturally salient species. Pairwise contrasts (Mann–Whitney with BH-FDR) identified several family pairs with adjusted $p < 0.05$, indicating that cultural versatility is not uniformly distributed across lineages. The distribution of species-level UV within the top families is shown in Figure 6.

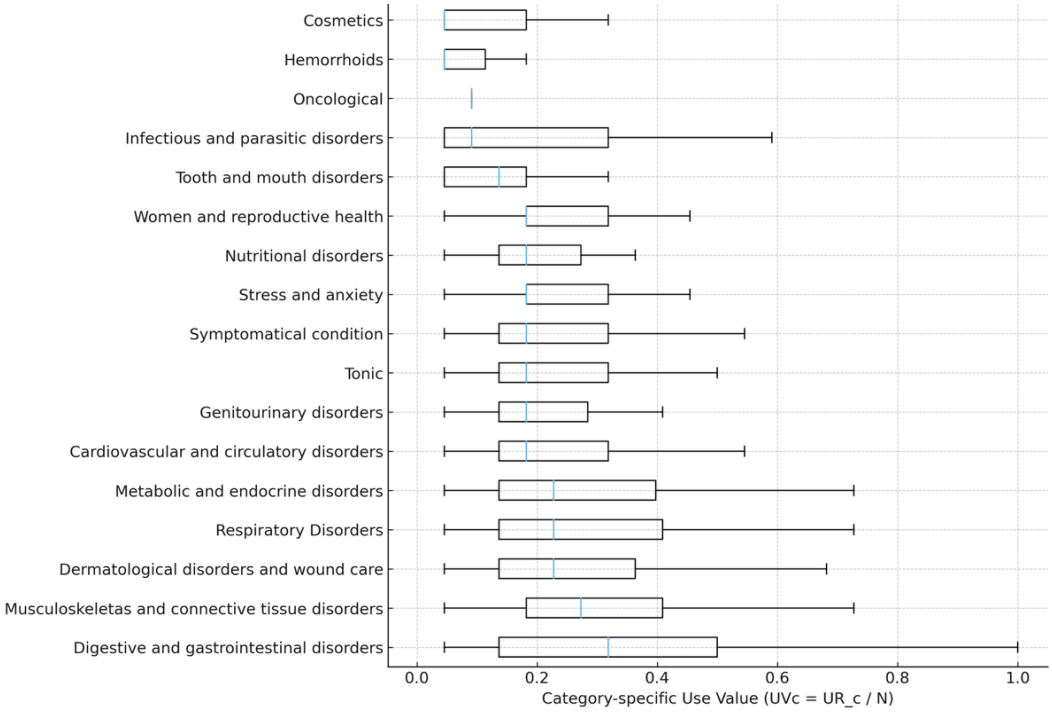

Figure 7. Category-specific Use Value (UVc = UR/N) across ailment domains. Horizontal boxplots ordered by median UVc. Domains with high median UVc correspond to those with high ICF, indicating strong agreement and concentrated use

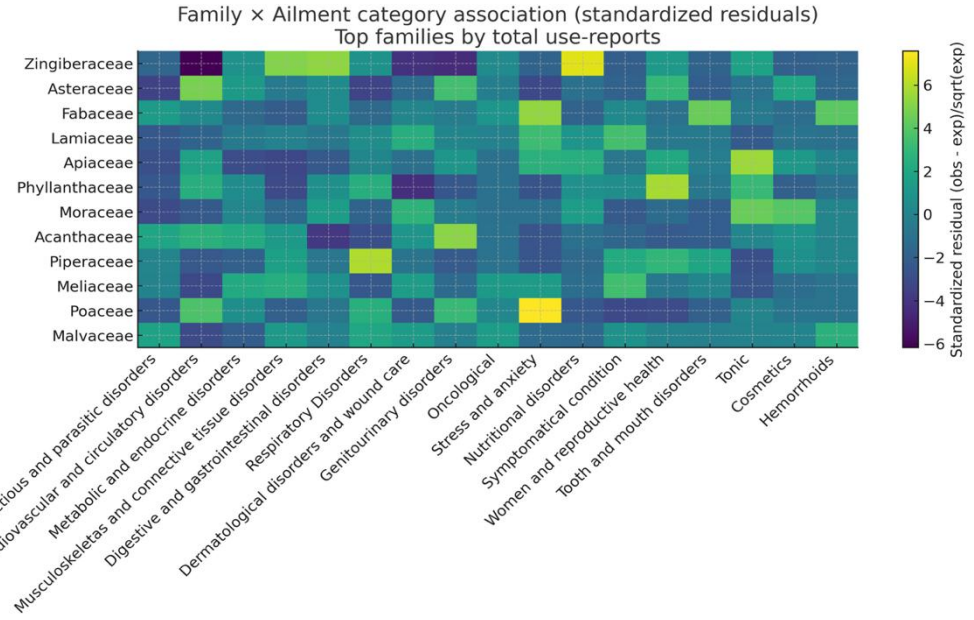

Figure 8. Heatmap of family and ailment category association

Category-specific Use Values (UVc) were contrasted across domains. A significant global difference was found, with the highest median UVc observed for domains that also showed high ICF, such as digestive and gastrointestinal disorders, metabolic and endocrine disorders, and musculoskeletal disorders. Pairwise tests (BH-adjusted) highlighted which category contrasts remain significant after multiple-testing correction (Figure 7).

A significant association between plant family and ailment category was detected (χ^2 = 3980.22). Over-representation was observed for Zingiberaceae in nutritional disorders (standardized residual +7.0) and digestive and gastrointestinal disorders (+5.3), with a secondary concentration in musculoskeletal conditions (+5.0). Asteraceae were strongly concentrated in dermatological and wound care (+9.4), Arecaceae in tooth and mouth disorders (+9.5/+8.5), Campanulaceae in women's reproductive health (+9.9), Clusiaceae in genitourinary (+13.0) and cardiovascular (+8.4), and Solanaceae in cardiovascular (+7.4). The complete matrix and residuals are provided in Figure 8 and Supplementary File S2.

Discussion

This ethnobotanical study highlights the profound significance of *Ubar Kampung* within Sundanese communities in West Java, Indonesia. Comparable ethnomedicinal traditions have been documented among the Sundanese and other Indonesian ethnic groups, emphasizing widespread reliance on traditional medicinal practices to manage both common acute ailments and chronic diseases (Nahdi 2016; Supiandi et al. 2021; Dewi et al. 2023; Julung et al. 2023; Agustina et al. 2024; Mulyanto et al. 2024). Despite increasing access to modern healthcare, the persistence of these practices underscores their resilience and adaptability, shaped by empirical knowledge transmitted through generations (Majeed et al. 2023).

Our study documents 111 medicinal plant species, with the prominence of specific plant families belonging to Zingiberaceae, Asteraceae, and Fabaceae. This finding is in accordance with previous studies conducted in West Java, where Zingiberaceae also contributed a high proportion of medicinal plants. Across different provinces, the dominant families can shift depending on local flora. In Java, herbaceous families like Zingiberaceae and Asteraceae lead, reflecting the abundance of cultivated spices and backyard medicinal herbs (Rahayu et al. 2024b). In contrast, studies in forest-rich areas like parts of Sumatra or Kalimantan might report more tree or woody families among the top ranks (Lestariningsih et al. 2023). Nonetheless, our study finds that many of the same families commonly used in West Java also appear in the ethnobotanical profiles of Central Kalimantan and Aceh, demonstrating a core set of plant lineages that are repeatedly relied upon for healing (Novaryatiin and Indah 2019; Asiandu and Sari 2024).

Regarding plant parts used, there is a strong consensus across studies. Leaves are the primary part utilized in our study, a pattern similar to that in most regions of Indonesia and worldwide. Leaves are often readily available throughout the year and contain abundant bioactive compounds, making them convenient for concoctions. Other common parts include rhizomes (for Zingiberaceae spices), bark, fruits, and flowers, depending on the species. This consistency in using leaf decoctions underscores a shared practical knowledge where boiling not only extracts potent compounds but also sterilizes the remedy, a technique long optimized in indigenous medicine (Putri et al. 2016; Weking et al. 2023; Raihandhany and Purnomo 2025).

The distribution of UV across families indicates that cultural versatility clusters within specific lineages, consistent with domestication/availability (e.g., spice–medicinal families) and long-standing culinary–therapeutic roles. The UVc analysis further shows that domains with high ICF also tend to exhibit higher median UVc, suggesting that shared community heuristics concentrate use-reports on a subset of species perceived as effective. Across Indonesia, considerable overlap in ethnomedicinal repertoires has been documented, with regional specializations superimposed on a shared core of taxa. In the present dataset, several top-ranked species coincide with reports from other provinces, indicating convergent cultural valuation. *Curcuma longa* L. and *Curcuma xanthorrhiza* Roxb. were widely cited for gastrointestinal complaints, women's health (postpartum recovery), and anti-inflammatory purposes, consistent with their prominence elsewhere; similarly, a Central Kalimantan survey identified *Curcuma zedoaria* (Christm.) Roscoe as the most frequently used species (Novaryatiin and Indah 2019). The use of *Zingiber* spp. was also ubiquitous. Among Lio healers in Flores, *Zingiber officinale* Roscoe and *Zingiber purpureum* Roscoe attained the highest UV (0.714), reflecting central roles in managing colds, fatigue, and digestive symptoms (Prasetyo et al. 2024). In the present study, multiple *Zingiber* species were likewise listed for comparable indications. These patterns suggest that widely cultivated spice–medicinal taxa (e.g., *Z. officinale*, *C. longa*, *Piper betle* L.) form a pan-Indonesian pharmacopoeial backbone, while locale-specific plants or uses (e.g., *Dillenia suffruticosa* (Griffith ex Hook.f. & Thomson) Martelli for skin ailments) capture microhabitat availability and community-specific knowledge transmission.

Together with our earlier RFC–UV correlation and FL signals (e.g., *Psidium guajava* L. for diarrhea; *Apium graveolens* L. for hypertension; *Swietenia mahagoni* L. Jacq for diabetes), these comparisons strengthen a data-driven prioritization which taxa from high-UV families that also show high FL for indications within high-ICF domains represent the most compelling candidates for ethnopharmacological validation. Complete agreement (FL = 100%) was observed for *P. guajava* in diarrhea (digestive disorders), *A. graveolens* in hypertension (cardiovascular disorders), *S. mahagoni* in diabetes (metabolic or endocrine disorders), *Kaempferia galanga* L. in rheumatism (musculoskeletal disorders), *Cymbopogon citratus* (DC.) Stapf in cough and sore throat (respiratory disorders), and *Sauropus androgynus* (L.) Merr. in lactation support (women's health and reproductive). Such high FL indicates that community use-reports for these taxa are tightly concentrated on a single therapeutic target, strengthening their candidacy for ethnopharmacological follow-up. Where relevant, these cultural signals align with emerging pharmacological evidence e.g., *P. guajava* for antibacterial and antidiarrheal effects (Liu et al. 2024), *A. graveolens* for antihypertensive action in a crossover trial and mechanistic support through calcium-channel blockade, diuresis, endothelial NO, and flavone constituents (Bencheikh et al. 2021; Alobaidi and Saleh 2024; Sohrabi et al. 2024). *Swietenia mahagoni* is widely reported for hypoglycemic activity including α-glucosidase inhibition and improvements in glycemic and antioxidant parameters, with formulation work (SNEDDS) further enhancing β-cell preservation in vivo (Sukardiman and Ervina 2020; Shiming et al. 2021; Ahamd et al. 2023; Taiyeb et al. 2024). These convergences do not equate to clinical efficacy but do indicate strong, triangulated leads.

Cultural salience (RFC) and versatility (UV) were found to be strongly associated at the species level, indicating that plants cited by more informants also tend to be reported for a broader range of uses. Because RFC aggregates citation frequency and UV aggregates use-reports, this association should be interpreted descriptively rather than causally; nonetheless, it supports an index-guided triage in which taxa with high ICF in their domain, high RFC/UV overall, and high FL for a specific indication are prioritized for pharmacological validation and conservation attention.

Taken together, these findings position *Ubar Kampung* as a robust, living knowledge system whose therapeutic core is broadly convergent with ethnobotanical profiles around Indonesia, yet retains locality-specific emphasis shaped by ecology and practice. The high informant consensus (ICF ≥ 0.85) in digestive and musculoskeletal categories indicates use patterns that are consistent with pharmacological plausibility (e.g., *P. guajava* for diarrhoea and *K. galanga* for rheumatism). These findings, through combining the emic-to-etic approach, both honor cultural logics and generate decision-grade evidence, enabling conservation-aware utilization and policy-relevant integration of *Ubar Kampung* within regional health systems.

Furthermore, the study has limitations which are attributed to the small quantity of sample size (n = 52), limiting its broader generalizability, highlighting the need for expanded surveys across diverse ecological and cultural contexts. Additionally, plant identification was performed solely through desk-based comparison of field photographs and vernacular descriptions with authoritative online and printed floras without collecting or preserving physical voucher specimens. As fieldwork documented an extensive list of medicinal plants, destructive sampling of plants is discouraged. Consequently, non-destructive photo-documentation and literature matching provided an ethically acceptable compromise. While this approach is widely used in rapid ethnobotanical inventories, it remains inferior to vouchers for long-term verification. For follow-on work, we therefore recommend that the highest-priority species be revisited, collected under appropriate permits, and documented by depositing duplicate voucher specimens in recognized herbaria to provide a permanent, citable reference. Additionally, a longitudinal study, which is crucial for understanding the long-term dynamics of plant use and knowledge transfer, that periodically samples diverse age groups and genders across additional Sundanese villages, is also necessary to clarify generational knowledge transfer, plant-use dynamics, and the resilience of *Ubar Kampung* under rapid socio-ecological change.

Within the ethical stewardship and cultural safeguards context, we recognize the risk that publishing traditional knowledge could facilitate commercialization that detaches practices from their cultural context. To mitigate this, our documentation is framed as community-respectful scholarship aimed at preservation and hypothesis generation, not exploitation. Any future use of these data for product development will proceed only with prior informed consent, mutually agreed terms, and access-and-benefit sharing with knowledge holders, in line with internationally recognized principles. We emphasize attribution of provenance, collaboration with community representatives, and mechanisms for fair benefit-sharing. These safeguards complement our ethically approved procedures and our focus on sustainable, culturally appropriate integration of local practices within regional health services.

In conclusion, the findings of this study emphasize the lasting importance *of Ubar Kampung* in maintaining health and cultural identity within Tatar Sunda, West Java. Several plant families emerge as therapeutically prominent, notably Zingiberaceae, Asteraceae, and Fabaceae. Moreover, these findings demonstrate significant consensus (ICF) and high Fidelity Levels (FL) for specific species used to address common ailments such as digestive disorders, infectious diseases, metabolic syndromes, and musculoskeletal conditions. Plants like *K. galanga, C. longa*, and *P. guajava* show strong cross-cultural validation, highlighting pharmacological concordance between folk usage and scientific evidence. The sustained use of *Ubar Kampung* holds implications beyond cultural preservation. However, the transmission of local knowledge to younger generations raises concerns for biodiversity and cultural continuity. Consequently, documenting and revitalizing traditional ethnobotanical expertise is thus essential, both to safeguard regional heritage and to facilitate responsible resource management.

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Supplementary Files

Table S1. Ethnobotanical uses, preparation methods, and quantitative indices (RFC and UV) of reported medicinal plants

Latin name	Family	Local name	Part(s) used	Preparation and application	Traditional medicinal uses	RFC	UV
Abelmoschus manihot (L.) Medik.	Malvaceae	*Daun nedi / Daun gedi*	Lf	Dc, oi	Fever, stomachache, mouth ulcers, hypertension, diabetes, lowering cholesterol, diarrhea, gastritis, wound healing, postpartum recovery, nausea, cough, sore throat, dermatitis, arthritis, menstrual cramps, immunity booster, sprain pain relief.	0.73	3.79
Abrus precatorius L.	Fabaceae	*Saga*	Lf	Dc, oi	Mouth ulcers, swollen gums, sore throat, cough, gout, blood sugar regulation, and headache relief.	0.62	3.39
Achyranthes aspera L.	Amaranthaceae	*Jarong, jarong lalaki*	Lf	Pd, ta, oi	Diuretic, relief pain in rheumatism, joint pain, stomachache, wound healing, urinary infections, diarrhea, postpartum care, blood sugar reduction, body odor reduction, hypertension control, ulcer treatment.	0.88	3.83
Acmella paniculata (Wall. ex DC.) R.K.Jansen	Asteraceae	*Jotang*	Fl	Dc, oi	Skin infection, immune booster, anti-cancer	0.23	1.52
Ageratum conyzoides L.	Asteraceae	*Babadotan*	Lf	Pd, ta	Burns, wound healing, dermatitis, itch relief, fever, eczema, mouth ulcer relief, hypertension, insect repellent, and acne.	0.62	2.68
Aglaia odorata Lour.	Meliaceae	*Pacar cina*	Lf	Dc, oi	Sore throat, cough, labor easing, antipyretic, menstrual regulation, childbirth pain relief, bad breath relief, eczema, postpartum recovery, and stress relief.	0.38	2.16
Allium cepa L.	Amaryllidaceae	*Bawang beureum*	Bb	Pd, ta, oi	Ulcers, acne, fever, cholesterol reduction, hypertension control, blood sugar control, wound disinfectant, and mild analgesic.	0.31	1.56
Allium fistulosum L.	Amaryllidaceae	*Bawang daun*	Lf	Dc, oi	Lowering blood pressure and cholesterol.	0.27	1.44
Allium sativum L.	Amaryllidaceae	*Bawang bodas*	Bb	Dc, oi	Cholesterol reduction, blood pressure control, antibiotics, diabetes, antivirals, immune boosters, and topical antiseptics.	0.96	2.28
Aloe vera (L.) Burm.f.	Asphodelaceae	*Lidah buaya*	Lf	Fc (gel)	Burns, acne, wound healing, hair care, ulcer treatment, immune booster, blood sugar control, eczema relief, hyperlipidemia, sunburn relief, oral ulcers, itch relief, skin dryness, psoriasis treatment.	0.88	2.96
Alpinia galanga (L.) Willd.	Zingiberaceae	*Laja goah*	Rh	Dc, oi	Carminative, rheumatism, back pain, anti-nausea, anti-flatulent, sore throat, cough, asthma, indigestion, diarrhea, cholesterol control, improved circulation, antifungal, blood sugar control, headache relief.	0.96	3.55
Alstonia scholaris (L.) R.Br., *Alstonia angustiloba* Miq.	Apocynaceae	*Lamé, pule, pulai*	Bk	Dc, oi	Sprained ankle, hypertension, respiratory disorders, wound healing, skin diseases, malaria, stomach pain, antiparasitic, dysentery, rheumatism, and immunity booster.	0.73	2.20
Alyxia reinwardtii Blume	Apocynaceae	*Pulasari*	Bk	Dc, oi	Fever, mouth ulcer, cough, and gastritis.	0.38	1.48
Amaranthus spinosus L.	Amaranthaceae	*Bayam duri*	Ap	Dc, oi	Diuretic, hypertension, edema, urinary tract infections, diabetes, body cooling tonic.	0.46	1.48
Amaranthus tricolor L.	Amaranthaceae	*Bayam merah*	Lf	Bl, oi	Diuretic, iron supplement, combats malnutrition, immunity booster, antihypertensive, wound healing, anemia treatment, kidney support, gastritis, and cholesterol lowering.	0.46	1.68
Amomum dealbatum Roxb.	Zingiberaceae	*Kapulaga lokal*	Rh	Dc, oi	Carminative, flatulence relief, diarrhea, indigestion, anti-ulcer, hypertension control, lactation support.	0.27	0.96

Anacardium occidentale L.	Anacardiaceae	*Jambu mede*	Lf	Dc, oi	Lactation support, antidiarrheal, infection, mouth ulcers, diabetes, cholesterol lowering, wound healing, antihypertensive, sore throat relief.	0.50	1.80
Ananas comosus (L.) Merr.	Bromeliaceae	*Ganas*	Fr	Fc	Blood sugar control, digestive aid, anti-bloating, antihypertensive, menstrual regulation, and cough relief.	0.46	1.72
Andrographis paniculata (Burm.f.) Nees	Acanthaceae	*Sambiloto*	Lf,st	Dc, oi	Hypertension control, diabetes, fever treatment, immune booster, detoxification, sore throat relief, joint pain relief, tonic.	0.96	2.96
Annona muricata L.	Annonaceae	*Sirsak*	Lf	Dc, oi	Diabetes, cancer prevention, hypertension, liver protection, wound healing, immune boosting, rheumatism, anemia, and skin diseases.	0.92	3.71
Anredera cordifolia (Ten.) Steenis	Basellaceae	*Binahong*	Lf	Dc, oi	Kidney disorders, fever, diabetes, gout, irregular menstrual cycles, mouth ulcers, hypertension, wound healing, blood sugar control, immunity booster, diuretic, cardiovascular health, menstrual health, migraine relief, nerve pain.	0.96	3.71
Antidesma bunius (L.) Spreng.	Phyllanthaceae	*Bencoy*	Fr	Fc, oi	Hypertension control, gout treatment, cough suppressant, menstrual cramps, immune booster, rheumatism.	0.54	1.80
Apium graveolens L.	Apiaceae	*Saledri*	Ap	Fc, oi	Hypertension, diuretic, cholesterol reduction, heart health, blood detoxification, vision support, kidney detox, appetite stimulant, liver support, menstrual regulation, insomnia treatment, respiratory tonic, lactation aid.	0.96	2.96
Apoballis rupestris (Zoll. & Moritzi ex Zoll.) S.Y.Wong & P.C.Boyce	Araceae	*Jotang*	Ap	Dc, oi	Appetite stimulant, wound healing, digestive health, sore throat remedy, pain relief, toothache, mouth ulcers, reduce bloating, muscle recovery, immune booster, bleeding gums, cough suppressant, and blood pressure regulation.	0.96	3.47
Arachis hypogaea L.	Fabaceae	*Su'uk*	Sd	Fc	Heart health, skin elasticity, digestive support.	0.08	0.56
Areca catechu L.	Arecaceae	*Jambe*	Sd	Fc, ta	Wound disinfectant, stamina enhancement, teeth strengthening, back pain relief, swollen gums, toothache, digestive booster, diuretic, cough relief, fatigue reduction.	0.73	2.80
Arenga pinnata (Wurmb.) Merr.	Arecaceae	*Kawung*	Sh	Dc, oi	Diabetes control, inflammation reduction, heart health, blood sugar regulation, muscle pain relief, relief from constipation, fatigue relief, and blood pressure control.	0.46	1.72
Artocarpus altilis (Park.) Fsb.	Moraceae	*Sukun*	Lf	Dc, oi	Wound healing, lowering blood glucose, lowering cholesterol, cough relief, immunity booster, blood circulation support, and appetite stimulant.	0.58	2.28
Artocarpus heterophyllus Lamk.	Moraceae	*Nangka*	Lf	Dc, oi	Rheumatism and gout treatment, diabetes control, lowering blood pressure, arthritis relief, nerve tonic, bloating relief, and cough suppressant.	0.58	2.12
Averrhoa bilimbi L.	Oxalidaceae	*Calincing*	Fr	Fc	Hypertension, diabetes, wound healing, acne treatment, sore throat, gastrointestinal disorders, insect bites, cholesterol reduction, kidney stones, and constipation relief.	0.81	2.80
Averrhoa carambola L.	Oxalidaceae	*Belimbing*	Fr	Fc	Cholesterol management, rheumatism, sore throat, immune booster, and digestion improvement.	0.65	1.96
Bambusa vulgaris Schrad. ex J.C.Wendl.	Poaceae	*Iwung*	Sh	Dc, bl	Hypertension control, wound healing, digestive health, cholesterol reduction, diabetes, and diarrhea.	0.35	1.04
Bidens pilosa L.	Asteraceae	*Jonge, Jonghe, Jeletun, Hareuga*	Lf	Dc	Wound healing, digestive ailments, cough, insect bites, menstrual disorders, gastritis, constipation treatment, and an immune booster.	0.35	1.36
Blumea balsamifera (L.) DC.	Asteraceae	*Sembung awéwé*	Lf, Rt	Dc	Diuretic, hypertension, kidney stone treatment, wound healing, diabetes, gastrointestinal ailments, skin infections, urinary tract infections, and postpartum recovery.	0.65	2.28

Boesenbergia rotunda (L.) Mansf.	Zingiberaceae	*Temu kunci*	Rh	Dc	Digestive health, rheumatism relief, cough and cold treatment, appetite stimulation, blood pressure control, wound healing, menstrual pain relief, postpartum recovery, joint pain relief, arthritis, and constipation treatment.	0.88	3.63
Bouea macrophylla Griff.	Anacardiaceae	*Gandaria*	Fr, Lf	Dc	Diabetes control, hypertension, cough relief, wound healing, digestive disorders, urinary tract infections, immune support, and sore throat.	0.38	1.36
Carica papaya L.	Caricaceae	*Gedang katés*	Lf	Bl	Dengue fever, sore throat, hypertension, diabetes, fever relief, cough, skin infections, ulcers, constipation relief, diarrhea, immune booster, and insect bites.	0.46	1.72
Ceiba pentandra Gaertn.	Malvaceae	*Randu*	Lf	Dc	Wound healing, cough remedy, digestive disorders, constipation relief, skin infections, pain relief, and ulcers.	0.27	1.04
Centella asiatica (L.) Urb.	Apiaceae	*Antanan*	Ap	Fc, Dc	Wound healing, cognitive enhancement, skin care, anxiety relief, memory booster, diabetes, hypertension, gastrointestinal disorders, ulcers, blood circulation improvement, postpartum recovery, cough, fatigue reduction, kidney health, constipation relief, insomnia treatment, respiratory ailments.	0.92	3.75
Chloranthus erectus (Buch.-Ham.) Verdc.	Chloranthaceae	*Cangkring*	Ap	Dc	Fever, rheumatism, arthritis, wound healing, digestive issues, cough, muscle pain, skin infections, diabetes, immune booster, constipation, and appetite stimulation.	0.50	2.08
Cinnamomum burmannii (Nees & T.Nees) Blume	Lauraceae	*Kayumanis cina*	Bk	Dc	Diabetes, hypertension, cholesterol reduction, gastrointestinal disorders, cough, digestive stimulant, appetite stimulant, obesity management, immune booster, and nausea relief.	0.62	2.04
Cinnamomum sintoc Blume	Lauraceae	*Sintok*	Lf	Dc	Wound healing, diabetes, cough remedy, hypertension management, fever, digestive disorders, skin care, rheumatism relief, joint pain management, arthritis, asthma treatment, constipation relief, liver tonic, immune booster, menstrual disorders, anti-aging, urinary tract infections, headache relief, diarrhea, postpartum care.	0.85	3.51
Clitoria ternatea L.	Fabaceae	*Telang*	Fls	Dc	Cognitive enhancer, anxiety reduction, fever relief, diabetes, wound healing, menstrual disorders, urinary disorders, hypertension management, immune booster, constipation relief, headache relief, insomnia relief, cough, and postpartum recovery.	0.81	3.36
Coleus scutellarioides (L.) Benth.	Lamiaceae	*Jawér kotok*	Lf	Dc	Wound healing, digestive disorders, constipation, skin itching relief, fever, headache relief, arthritis management, respiratory ailments, cough relief, anemia relief, blood sugar control (diabetes), hypertension relief, obesity control, eczema treatment, immune booster, stomachache relief.	0.73	2.92
Coriandrum sativum L.	Apiaceae	*Katuncar*	Sd	Dc	Digestive stimulant, appetite enhancer, respiratory ailments, and immune booster.	0.23	0.92
Cosmos caudatus Kunth.	Asteraceae	*Randa midang, kenikir*	Lf	Dc	Lowering blood pressure, diabetes, digestive stimulant, appetite enhancer, immune booster, gastrointestinal disorders, and cholesterol reduction.	0.69	1.92
Costus speciosus J.Koenig	Costaceae	*Pacing*	St	Dc	Controlling blood sugar, hypertension relief, digestive disorders, wound healing, arthritis relief, cough treatment, respiratory conditions, constipation relief, gastrointestinal problems, skin infections, rheumatism management.	0.50	1.92
Crassocephalum crepidioides (Benth.) S.Moore	Asteraceae	*Sintrong*	Lf	Fc	Digestive stimulant, wound healing, diabetes, hypertension relief, arthritis relief, gastrointestinal disorders, immune booster, constipation relief, cough remedy, fever reduction, skin infections, postpartum care, joint pain relief, rheumatism management, appetite enhancement, fatigue reduction.	0.77	3.16

Cucurbita moschata Duchesne	Cucurbitaceae	*Waluh*	Sd	Dc	Diabetes management, hypertension, wound healing, kidney health, constipation relief, obesity management, cardiovascular health, skin care, gastrointestinal disorders, immune booster, cholesterol control, arthritis, joint pain relief, fever relief, urinary tract disorders.	0.88	2.72
Curcuma longa L. *(syn. Curcuma domestica)*	Zingiberaceae	*Konéng lalab*	Rh	Dc, oi	Diabetes control, wound healing, hypertension, digestive aid, immune booster, menstrual pain relief, liver detoxification, cholesterol reduction, obesity management, and gastrointestinal health.	1.00	4.07
Curcuma xanthorrhiza Roxb.	Zingiberaceae	*Temulawak, Konéng gedé*	Rh	Dc, oi	appetite stimulant, liver tonic, digestive aid, diabetes, hypertension, cholesterol reduction, immune booster, menstrual disorders, obesity control, wound healing, gastrointestinal disorders, anemia relief, respiratory disorders, postpartum tonic, and kidney health.	0.96	4.03
Curcuma zedoaria (Christm.) Roscoe	Zingiberaceae	*Konéng bodas*	Rh	Dc, oi	Diabetes control, appetite stimulant, digestive stimulant, wound healing, menstrual pain relief, arthritis relief, cholesterol reduction, hypertension control, gastrointestinal disorders, immune booster, obesity management, postpartum care, anemia treatment, asthma relief, and kidney disorders.	0.77	3.20
Cycas rumphii Miq.	Cycadaceae	*Pakis haji*	Rt	Dc, oi	Rheumatism relief, arthritis, digestive stimulant, diabetes, hypertension management, wound healing, urinary disorders, joint pain relief, gastrointestinal disorders, immune booster, skin infections, and constipation relief.	0.77	2.88
Cyclea barbata Miers	Menispermaceae	*Cincau*	Lf	Pd, oi	Digestive aid, constipation relief, diabetes, hypertension control, fever reduction, urinary disorders, wound healing.	0.77	2.44
Cymbopogon citratus (DC.) Stapf	Poaceae	*Sereh*	Rt	Dc, oi	Anxiety relief, insomnia treatment, fatigue reduction, cough remedy, sore throat, digestive stimulant,	0.96	3.87
Dracaena angustifolia (Medik.) Roxb.	Ruscaceae/ Asparagaceae	*Daun Suji*	Lf	Dc, oi	Wound healing, fever reduction, anemia relief, digestive stimulant, hypertension management, diabetes, immune booster, cough relief, gastrointestinal issues, insomnia relief, and anti-aging.	0.77	3.12
Elephantopus scaber L.	Asteraceae	*Tapak liman*	Rt	Dc, oi	Gastrointestinal health, arthritis management, wound healing, fever reduction, kidney health, digestive disorders, urinary tract infections, cough relief, respiratory ailments, diabetes, hypertension relief, joint pain management, constipation relief, rheumatism relief.	0.85	3.43
Erythrina subumbrans (Hassk.) Merr.	Fabaceae	*Dadap*	Lf	Dc	Hypertension relief, diabetes, fever treatment, wound healing, arthritis relief, cough remedy, respiratory disorders, digestive aid, menstrual disorders, postpartum recovery, gastrointestinal health, constipation relief, anemia relief, immune booster, joint pain relief, kidney disorders, liver protection, urinary infections, obesity management, headache relief, skin health, insomnia relief, rheumatism relief.	0.88	3.71
Ficus septica Burm.f.	Moraceae	*Ki ciyat*	Lt, fr	Ta	Wound healing, skin infections, digestive disorders, constipation relief, diarrhea treatment, skin rashes, and eczema.	0.88	3.63
Ficus virens Aiton	Moraceae	*Bunut*	Lf	Dc, oi	Wound healing, relief of stomachache, cough remedy, relief of pain in arthritis, menstrual disorders, postpartum care, gastrointestinal disorders, constipation relief, anemia treatment, skin infections, joint pain relief, liver protection, kidney health, immune booster, obesity management, headache relief, urinary disorders, insomnia relief, diarrhea treatment, anemia relief.	0.88	3.71
Garcinia mangostana L.	Clusiaceae	*Manggis*	Fr (peel)	Dc, oi	Cancer prevention, diabetes, hypertension relief, immune booster, obesity management, and cholesterol management.	1.00	2.28

Gigantochloa apus (Schult. & Schult.f.) Kurz	Poaceae	*Awi tali, apus*	Lf	Dc, oi	Wound healing, digestive disorders, arthritis relief, joint pain management, constipation relief, and skin infections.	0.23	0.92
Gnetum gnemon L.	Gnetaceae	*Tangkil*	Fr	Dc, oi	Immune booster, constipation relief, wound healing, hypertension relief, diabetes, arthritis management, digestive stimulant, cholesterol control, anemia treatment, gastrointestinal disorders, skin health, and obesity control.	0.62	2.32
Goniothalamus macrophyllus (Blume) Zoll.	Annonaceae	*Ki cantung*	Rt	Dc, oi, ta	Rheumatism, arthritis, gout, digestive disorders, wound healing, hypertension, joint pain, kidney health, gastrointestinal disorders, constipation relief, urinary disorders, and fatigue relief.	0.69	2.72
Graptophyllum pictum (L.) Griff.	Acanthaceae	*Handeuleum*	Lf	Dc, oi, fc	Hemorrhoids, wound healing, fever treatment, diabetes, hypertension relief, postpartum recovery, joint pain management, arthritis relief, immune booster, constipation relief, diarrhea, liver protection, kidney health, skin care, anemia relief, and obesity management.	0.85	3.16
Gynura divaricata (L.) DC.	Asteraceae	*Dewa*	Lf	Dc, oi	Diabetes management, hypertension relief, gastrointestinal health, immune booster, constipation relief, obesity management, fever treatment, cough remedy, diarrhea relief, and fatigue reduction.	0.88	3.47
Gynura procumbens (Lour.) Merr.	Asteraceae	*Sambung nyawa*	Lf	Dc, oi	Diabetes management, hypertension relief, wound healing, cholesterol reduction, immune booster, arthritis management, joint pain relief, menstrual cramps, postpartum care, skin conditions, liver protection, kidney health, headache relief, obesity control, anemia treatment.	0.96	3.39
Hippobroma longiflora (L.) G.Don	Campanulaceae	*Korejat*	Fl	Dc, oi	Eye infections, wound healing, respiratory disorders, cough remedy, gastrointestinal ailments, menstrual cramps, postpartum recovery, and skin infections.	0.73	2.88
Imperata cylindrica (L.) Beauv.	Poaceae	*Jukut eurih (alang-alang)*	Ap	Dc, oi	Kidney stone, diuretic, hypertension relief, cough remedy, digestive aid, joint pain management, obesity management, diarrhea relief, fatigue reduction, and gastrointestinal disorders.	0.92	2.84
Kaempferia angustifolia Roscoe	Zingiberaceae	*Kunci*	Rh	Dc, oi	Digestive ailments, respiratory ailments, cough, wounds, infection, rheumatism, ulcers, toothache, dyspepsia, dizziness, tonic, skin conditions, menstrual disorders, appetite stimulant, nausea, muscular pain.	0.96	4.03
Kaempferia galanga L.	Zingiberaceae	*Kencur*	Rh	Dc, oi	Rheumatism, back pain, joint pain, fever, inflammation, postpartum tonic, menstrual pain, respiratory ailments, cough, digestive disorders, bronchitis.	1.00	4.15
Kalanchoe pinnata (Lam.) Pers.	Crassulaceae	*Cocor bebek*	Lf	Fc, ta, oi	Fever, wound healing, toothache, cough, burns, hypertension, arthritis, rheumatism, eczema, insect bites, urinary infections.	0.54	2.12
Melastoma malabathricum L.	Melastomataceae	*Harendong*	Fr	Dc, oi	Diarrhea, wounds, stomachache, toothache, postpartum care, hemorrhoids, burns, thrush, ulcers, menstrual pain, cuts, infection, fever, bleeding, rheumatism, skin diseases, swelling, cough, sore throat, abdominal cramps.	0.96	3.59
Melochia umbellata (Houtt.) Stapf	Malvaceae	*Bintinu*	Bk	Dc, oi	Fever, cough, wounds, diarrhea, skin infections, bronchitis, dysentery, abdominal pain, diabetes, malaria, hepatitis, rheumatism, stomachache, headache, jaundice, sore throat, insect bites, urinary tract infections.	0.96	3.71
Mimosa pudica L.	Fabaceae	*Putri malu*	Ap	Dc, oi, ta	Rheumatism, wounds, insomnia, bleeding, diarrhea, inflammation, skin infections, anxiety, asthma, bronchitis, toothache, hemorrhoids, fever, diabetes, snake bites, ulcers, hypertension, jaundice, liver disorders, edema, dysentery, swelling.	1.00	3.83

Momordica charantia L.	Cucurbitaceae	*Paria*	Lf, Fr	Dc, oi, ta	Diabetes, gout, hypertension, fever, stomachache, jaundice, wounds, digestive disorders, diarrhea, skin conditions, infections, ulcers, constipation, antiviral, menstrual pain, dysentery, inflammation, malaria, asthma, headache, cough, colds, rheumatism.	0.92	3.20
Morinda citrifolia L.	Rubiaceae	*Cangkudu (mengkudu)*	Fr	Dc, oi, ta	Hypertension, diabetes, digestive disorders, cough, colds, wounds, arthritis, rheumatism, infection, antiviral, cancer prevention, dysentery, menstrual pain, kidney problems, skin infections, inflammation, headache, asthma, liver ailments, ulcers, malaria, diarrhea, depression, immune enhancement, fatigue.	0.96	3.59
Moringa oleifera Lam.	Moringaceae	*Kelor*	Lf	Bl, oi	Toothache, headache, diarrhea, menstrual pain, anemia, diabetes, hypertension, inflammation, arthritis, skin infections, cough, colds, wound healing, liver ailments, urinary infections, edema, malnutrition, asthma, gastrointestinal disorders, fever, eye infections, rheumatism, thyroid dysfunction.	0.88	3.59
Muntingia calabura L.	Muntingiaceae	*Kersen*	Lf, Fr	Dc, oi, ta	Lowering cholesterol, diabetes, hypertension, gout, ulcers, cough, diarrhea, infection, wound healing, headaches, asthma, stomachache, toothache, fever, urinary infections, colds, analgesics, dysentery, skin diseases, insomnia, constipation, kidney problems, liver problems.	0.88	3.43
*Murraya paniculata (*L.) Jack	Rutaceae	*Kamuning*	Lf	Dc, oi, ta	Toothache, skin infections, diarrhea, dysentery, fever, rheumatism, cough, colds, bronchitis, sore throat, menstrual pain, hypertension, diabetes, headaches, joint pain, asthma, digestive disorders, jaundice, snake bites, anxiety, urinary disorders, hair tonic, earache, dizziness.	0.96	3.71
Ocimum basilicum L.	Lamiaceae	*Surawung*	Lf	Dc, oi, ta	Diabetes, cough, cold, headache, fever, digestive ailments, wound healing, insect repellent, stomachache, anxiety relief, nausea, menstrual pain, asthma, respiratory problems, arthritis, toothache, ulcers, skin diseases, insomnia, hypertension, diarrhea, dizziness.	0.85	3.55
Oenanthe javanica DC.	Apiaceae	*Tespong*	Lf	Dc, oi	Hypertension, diabetes, fever, inflammation, liver disorders, digestive problems, respiratory infections, kidney ailments, wound healing, cough, headache, dizziness, bronchitis, urinary disorders, anemia, arthritis, rheumatism, detoxification, menstrual pain, swelling, constipation, appetite stimulant, postpartum tonic, urinary tract infections.	0.92	3.91
Oroxylum indicum (L.) Kurz.	Bignoniaceae	*Pongporang*	Rt	Dc, ta, oi	Rheumatism, diarrhea, inflammation, respiratory diseases, cough, asthma, jaundice, stomachache, dysentery, wounds, ulcers, fever, anticancer, kidney disorders, diabetes, sore throat, earache, liver disorders, hemorrhoids, menstrual disorders, headache, bronchitis, snakebite treatment, hypertension, arthritis.	0.96	3.79
Orthosiphon aristatus (Blume) Miq.	Lamiaceae	*Kumis ucing*	Lf	Dc, oi, ta	Back pain, hypertension, gout, urinary tract infections, kidney stones, muscle soreness, arthritis, inflammation, diabetes, edema, fever, liver disorders, diuretic, rheumatism, digestive problems, cholesterol management, headaches, obesity.	0.81	3.12
Pandanus amaryllifolius Roxb. ex Lindl.	Pandanaceae	*Pandan*	Lf	Dc, oi	Hypertension, muscle soreness, diabetes, diuretic, insomnia, inflammation, arthritis, rheumatism, fever, cold, cough, wounds, skin infections, constipation, postpartum care, urinary disorders, stomach cramps	0.96	3.63
Phyllanthus acidus (L.) Skeels	Phyllanthaceae	*Cereme*	Lf, Fr	Fc, oi	Mouth ulcers, diabetes, hypertension, stomachache, rheumatism, constipation, digestive disorders, and sore throat.	0.85	2.68

Phyllanthus emblica L.	Phyllanthaceae	*Malaka*	Fr	Dc, oi	Diabetes, hypertension, cough, sore throat, inflammation, constipation, cold, and asthma.	1.00	3.47
Physalis angulata L.	Solanaceae	*Cecendet*	Rt	Dc, oi	Diabetes, wound healing, fever, infection, wounds, skin diseases, urinary infections, dermatitis.	1.00	2.60
Piper betle L.	Piperaceae	*Seureuh*	Lf	Dc, oi, ta, gg	Vaginal discharge, postpartum healing, bad breath, antiseptic, wounds, digestive disorders, bleeding gums, toothache, infection, antifungal, cough, diabetes, fever, headache, skin infections, mouth ulcers, respiratory ailments, hypertension, bronchitis, hemorrhoids, rheumatism, throat infections, insect bites.	0.92	3.32
Piper crocatum Ruiz & Pav.	Piperaceae	*Seureuh beureum*	Lf	Fc, oi, gg	Nosebleed, diabetes, wound healing, hypertension, inflammation, menstrual pain, vaginal discharge, cough, asthma, sore throat, headache, diarrhea, urinary infections, stomachache.	1.00	3.67
Piper nigrum L.	Piperaceae	*Lada hitam*	Fr	Dc, oi	Cough, digestive disorders, asthma, arthritis, rheumatism, appetite stimulant, diarrhea, fever, cold remedy, sore throat, skin diseases, fatigue, gastrointestinal ailments.	0.96	3.99
Plantago major L.	Plantaginaceae	*Ki urat*	Rt	Dc, oi, gg	Muscle pain, arthritis, gout, skin burns, inflammation, wound healing, fever, urinary tract infections, bronchitis, cough, diarrhea, diabetes, ulcers, insect bites, rheumatism, kidney disorders, hemorrhoids, hypertension, eczema, constipation, sore throat, and mouth ulcers.	0.96	3.47
Plectranthus scutellarioides (L.) R.Br.	Lamiaceae	*Jawer kotok*	Lf	Fc, oi	Constipation, itchy skin, hemorrhoids, postpartum recovery, wound healing, inflammation, skin diseases, fever, diarrhea, cough, menstrual pain, stomachache, digestive disorders, rheumatism, headache, bronchitis, hypertension, diabetes, anxiety, insect bites, eczema, muscle pain, anemia, dizziness.	0.96	3.87
Pluchea indica (L.) Less.	Asteraceae	*Beluntas*	Lf	Dc, oi, ta	Vaginal discharge, body odor, menstrual pain, acne, digestive disorders, rheumatism, diarrhea, hypertension, skin infections, and bronchitis.	1.00	3.79
Polyscias scutellaria (Burm.f.) Fosb.	Araliaceae	*Mamangkokan*	Lf	Dc, oi, ta	Rheumatism, wounds, postpartum care, hair growth stimulant, diarrhea, inflammation, asthma, headache, bronchitis, anxiety, insomnia, skin disorders, edema, anemia, toothache, stomachache, constipation.	1.00	4.27
Psidium guajava L.	Myrtaceae	*Jambu biji*	Lf, Fr	Dc, oi, ta*	Diarrhea, dysentery, hypertension, diabetes, wounds, skin infections, hemorrhoids, digestive disorders, nausea, gastrointestinal bleeding.	1.00	2.52
Psophocarpus tetragonolobus (L.) DC.	Fabaceae	*Ja'at*	Fr	Dc, oi	Diabetes, infection, hypertension, digestive disorders, cough, kidney disorders, and rheumatism.	1.00	2.36
Pterocarpus indicus Willd.	Fabaceae	*Angsana*	Lt	Ta	Toothache relief, wound healing, infection, ulcers, and hypertension.	0.73	1.92
Punica granatum L.	Lythraceae	*Dalima*	Fr, Peel	Dc, oi, fc	Diarrhea, dysentery, wound healing, hypertension, diabetes, ulcers, skin infections, gastrointestinal disorders, toothache, fever, arthritis, bleeding gums, vaginal discharge, throat infections, menstrual disorders, and constipation.	0.92	3.32
Sandoricum koetjape Merr.	Meliaceae	*Kecapi*	Fr	Dc, ta	Fever, wounds healing, diabetes, digestive disorders, constipation	0.96	4.03
Sauropus androgynus (L.) Merr.	Phyllanthaceae	*Katuk*	Lf	Dc, fc, oi	Breast milk production, anemia, postpartum recovery, urinary infections, and appetite stimulants.	1.00	3.39
Solanum torvum	Solanaceae	*Takokak*	Fr	Dc, oi	Diabetes, hypertension, inflammation, rheumatism, menstrual pain, urinary disorders, and insect bites.	0.96	3.36
Sonchus arvensis L.	Asteraceae	*Tempuyung*	Ap	Dc, oi	Kidney stones, diuretic, hypertension, wound healing, and diabetes.	1.00	2.44
Staurogyne elongata Kuntze	Acanthaceae	*Reundeu*	Lf	Dc, oi	Hypertension, diabetes, diuretic, wounds, rheumatism, asthma, skin infections, ulcers.	0.58	2.12

Strobilanthes crispa (L.) Blume	Acanthaceae	*Pecah beling*	Lf	Dc, oi	Kidney stones, diuretic, hypertension, infection, urinary disorders, skin infections, urinary tract infections.	0.92	2.24
Swietenia mahagoni (L.) Jacq.	Meliaceae	*Mahoni*	Sd	Dc, oi	Diabetes, hypertension, malaria, inflammation, fever, skin diseases, arthritis, wound healing, antiviral, constipation, ulcers, rheumatism, fatigue.	0.96	3.51
Syzygium polyanthum (Wight) Walp.	Myrtaceae	*Salam*	Lf	Dc, oi	Lowering cholesterol, diabetes, hypertension, ulcers, cough, rheumatism, skin infections, and toothache.	1.00	3.00
Tinospora crispa (L.) Hook.f. & Thomson	Menispermaceae	*Bratawali*	St	Dc, ta	Diabetes, appetite stimulant, fever, hypertension, digestive disorders, cough, liver ailments, gout, rheumatism, skin infections, ulcers, diarrhea, constipation, asthma, wounds.	0.92	3.47
Wurfbainia compacta (Sol. ex Maton) Skornick. & A.D.Poulsen	Zingiberaceae	*Kapulaga*	Rh	Dc, oi	Low back pain, arthritis, digestive disorders, cough, stomachache, rheumatism, asthma, dizziness, fatigue.	1.00	3.87
Zingiber cassumunar Roxb. *syn. Zingiber purpureum* Roscoe	Zingiberaceae	*Panglay (bangle)*	Rh	Dc, oi	Rheumatism, arthritis, wounds, stomachache, infection, digestive disorders, constipation, anemia, joint pain, skin infections, gastrointestinal issues, urinary infections.	1.00	3.83
Zingiber zerumbet (L.) Roscoe ex Sm.	Zingiberaceae	*Lampuyang*	Rh	Dc, oi	Hypertension, diabetes, digestive disorders, asthma, wounds, cough, fever, rheumatism, ulcers, menstrual disorders, stomachache, fatigue, headaches, respiratory ailments, arthritis, postpartum tonic, diarrhea.	1.00	4.07

Note: Plant parts used: Aerial part (Ap), Leaf (Lf), Root (Rt), Rhizome (Rh), Bark (Bk), Fruit (Fr), Seed (Sd), Herbs, Flower (Fl), Bulb (Bb), Stem (St), Tuber (Tb), Latex (Lt); Preparation and application methods: Decoction (Dc), Pounding (Pd), Boiling then consumed the plants parts (bl), Grated (gt), fresh consumed as lalapan (fc), Gargled as mouthwash (gg), Oral ingestion (oi), Topical application to the affected site (ta), *Folded then directly stuffed into the nose

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Ethnobotanical validation of plant extracts for sustainable management of fall armyworm

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Abstract. *Labonete HJP, Ancheta DJ, Modina RMR, Yongco JE, Torres MAJ, Demayo CG. 2025. Ethnobotanical validation of plant extracts for sustainable management of fall armyworm. Asian J Ethnobiol 8: 222-229.* Ethnobotanical practices offer essential insights for pest management in smallholder farming. In the Philippines, the use of chili (C*apsicum frutescens*), madre de cacao (*Gliricidia sepium*), and lemongrass (*Cymbopogon citratus*) as botanical insecticides is based on farmers' knowledge and indigenous traditions, yet their effectiveness against transboundary crop pest fall armyworm (*Spodoptera frugiperda*) remains untested. To address this gap, the sublethal effects of crude botanical extracts on third-instar *S. frugiperda* larvae were studied under laboratory conditions. All extracts produced dose-dependent sublethal effects: lemongrass caused the strongest feeding suppression (28.7%) and induced developmental malformations in larvae (5.0%), pre-pupae (6.3%), pupae (14.3%), and adults (7.1%); chili delayed development by up to 7 days and reduced survival to 45%; and madre de cacao deterred feeding mainly in dual-choice assays (antifeedant index=49.2%), suggesting efficacy for intercropping. This is the first validation of crude aqueous extracts for *S. frugiperda*, demonstrating the potential of farmer-based botanical insecticides as an addition to integrated pest management (IPM). The findings highlight how locally adapted practices, grounded in ancestral and community knowledge, can contribute to agroecology and strengthen food security by advancing sustainable, low-cost, and eco-friendly alternatives to synthetic pesticides. However, to fully realize this potential, further field-based trials and phytochemical characterization are crucial and should be the focus of future research.

Keywords: Biological parameters, crude extracts, fall armyworm, natural insecticide, traditional knowledge

INTRODUCTION

Ethnobotanical insecticides are gaining renewed attention for their ability to merge ecological safety with cultural relevance, building on the long-standing reliance by indigenous communities and smallholder farmers who use insecticidal plants as affordable, effective, and biodegradable alternatives to synthetic applications. For thousands of years, crude botanical extracts rich in secondary metabolites have provided antifeedant effects, target specificity, and preservation of natural pest enemies, resulting in residue-free crops, enhanced biodiversity, and sustainable agriculture (Pavela 2016). This is evident in the Philippines, an agricultural country that harbors thousands of endemic vascular plant species used by diverse ethnic groups. In a recent review, 112 primarily native plant species have been documented to be utilized as botanical insecticides by indigenous people (IPs) and local farmers in the Philippines, with *Capsicum*, *Cymbopogon*, and *Gliricidia sepium* as the most cited genera and species (Labonete et al. 2025).

Among the promising botanicals, *Cymbopogon citratus* (lemongrass), *Capsicum frutescens* (chili), and *Gliricidia sepium* (madre de cacao) stand out as culturally and agriculturally significant species. *Cymbopogon citratus* is among the most widely adopted botanicals, integrated by farming communities into intercropping systems for its natural repellency. At the same time, aqueous leaf extracts mixed with soap are sprayed on crops for its strong aromatic and insecticidal properties. In contrast, *C. frutescens* has long been favored by rice and chili farmers, with crude fruit extracts commonly sprayed on leaves for its pungent effects that irritate insect pests. *Gliricidia sepium*, on the other hand, serves as a living barrier in intercropping, provides aqueous leaf sprays, and is burned for defogging. Despite their widespread cultural significance and long-standing use by farming communities, crude aqueous extracts remain largely untested in controlled experiments, creating a gap between traditional practice and scientific validation. The growing interest in natural plant products underscores the urgent need for scientific evaluation of their bioactive compounds (Ejeta et al. 2021), which are selective and environmentally safe, making them valuable for sustainable pest management, food security, and agroecosystem development through continued cultivation and mixed-cropping. With the rise of transboundary pests and diseases, the long-standing use of *C. citratus*, *C. frutescens*, and *G. sepium* across regions highlights their promise as candidates for laboratory verification.

The fall armyworm *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) has rapidly emerged as a major transboundary pest in Southeast Asia since it arrived in 2018, causing widespread damage to staple cereal crops (Kusano et al. 2025). In the Philippines, infestations threatening millions of hectares of corn and rice have driven heavy reliance on chemical pesticides, highlighting the need for stronger, eco-friendly, plant-based alternatives (Labonete et al. 2024). Despite the long-standing ethnobotanical use of *C. citratus, C. frutescens,* and *G. sepium* by farming communities as crude aqueous sprays or intercrop repellents, their potential impact on *S. frugiperda* remains largely unexplored under controlled conditions. This study hypothesizes that these crude extracts, prepared using traditional methods with soap, exert measurable sublethal effects on the pest's growth, development, and feeding behavior. Larval responses in dual-choice and no-choice feeding assays, along with pupal and adult biological parameters and morphological development, are assessed to connect local practices with experimental validation.

MATERIALS AND METHODS

Study area

Insect rearing, dose-setting experiments and bioassays were conducted at the Center of Integrative Health (CIH) Laboratory, Premier Research Institute of Science and Mathematics (PRISM), Mindanao State University–Iligan Institute of Technology (MSU-IIT), Iligan City, Philippines under ambient conditions (28.6±5.6°C; 70-80% RH) optimal for larval development (Pavana et al. 2023). Crude botanical extract preparation and data collection were performed at the Molecular Ecology and Physiology Laboratory, PRISM, MSU-IIT.

Spodoptera frugiperda culture

Sixth-generation corn-reared *Spodoptera frugiperda* larvae from Davao Oriental State College of Science and Technology, Mati, Davao Oriental, were transported to the CIH Laboratory, PRISM, MSU-IIT. Larvae were reared under controlled conditions (28.6±5.6°C; 70-80% RH; 16:8 L:D photoperiod) until pupation, fed with clean castor (*Ricinus communis*) leaves. Castor leaves were selected as a highly suitable host for *S. frugiperda*, supporting rapid development, high fecundity, balanced sex ratio, and zero larval mortality under laboratory conditions (Salem et al. 2023; Tura et al. 2025). Pupae were placed in 100 mL tissue-lined containers. Upon emergence, adult moths were provided with a 10% honey solution and a potted two-week-old yellow corn plant for oviposition. Eggs were collected every two days by cutting corn leaves, then placed in small containers for cohort rearing. Larval cohorts were standardized by monitoring head capsule molting every 12 h. Bioassays used third-instar larvae starved for 4 h, with fresh, clean, untreated castor leaves as test material. Ethics clearance was granted by the MSU-IIT Research Integrity and Compliance Office, with an IACUC protocol exemption (202500031B).

Ethnobotanical basis

The test plants were selected based on a recent ethnobotanical review of pesticidal plants in the Philippines (Labonete et al. 2025), complemented by observations of local farming practices in Iligan City, Northern Mindanao. Madre de cacao (*G. sepium*) is collected from an organic intercrop system as a plant barrier. At the same time, chili (*C. frutescens*) fruits and lemongrass (*C. citratus*) stalks and leaves are purchased through organic farmers' markets, utilized for household and crop protection. Correct plant identification was certified by a botanist from the Department of Biological Sciences (DBS), MSU-IIT. Crude extracts were prepared following traditional methods.

Preparation of crude extracts

Leaves of madre de cacao (*G. sepium*), fruits of chili (*C. frutescens*), and stalks and leaves of lemongrass (*C. citratus*) were shade-dried, ground to a fine powder, and 10% w/v extracts were prepared by soaking 100 g of powder in 1 L of water containing 0.1% Tween 80 for 24 h at room temperature (Phambala et al. 2020). This technique provides a safe, cost-effective way to utilize plant bioactive compounds for experimental evaluation. Extracts were filtered, stored in cool, dark conditions, and diluted to target concentrations for dose-setting and bioassays. Methomyl, an insecticide effective against *S. frugiperda* (Salem et al. 2023), was used as the positive control, and distilled water served as the negative control.

Experimental setup

Feeding preference bioassays followed a Randomized Block Design (RBD) with third-instar larval cohort identified by hatch date as the block. Two factors were considered: (i) the botanical extract applied (*G. sepium*, *C. frutescens*, *C. citratus*); and (ii) choice type (dual-choice, no-choice), with 20 replicates per treatment combination. Larval growth and development assays used a Completely Randomized Design (CRD) with five treatments: three botanical extracts, positive control (methomyl), negative control (distilled water), with twenty 3rd instar single-larval replicates per treatment.

Dose-setting experiment to determine sub-lethal concentrations

A preliminary dose-setting experiment was conducted to determine extract concentrations for subsequent bioassays and estimate LC_{30} values, following established approaches for sublethal testing (Pavana et al. 2023). LC_{30} was selected as a low lethal concentration to assess antifeedant and developmental effects without causing high mortality, consistent with recommendations for integrated pest management studies (Desneux et al. 2007). Third-instar larvae, pre-starved for 4 h, were used for all assays. Initial toxicity screening involved five concentrations (0.1, 0.5, 1, 5, and 10%), prepared by diluting the extracts in distilled water. Twenty single-larval replicates per treatment were maintained in ventilated plastic containers. Castor (*R. communis*) leaf discs (5 cm diameter, ~1.5 g) were dipped in the treatments, shade-dried for 10 min,

before introducing them to the larvae. Untreated leaves served as negative controls, while the positive control, methomyl, was applied at an LC_{30} based on Salem et al. (2023) and computed from lab results. Leaves were replaced every 24 h. Total mortality was assessed at 120 h, with non-responsive larvae considered dead. Rates were corrected using Abbott's formula, and log concentration–mortality regression lines were generated to calculate LC_{30} values for subsequent experiments.

Antifeedant experiments: Dual-choice and no-choice assays

Antifeedant activity was evaluated using the LC_{30} concentrations of crude botanical extracts. Castor leaf discs were treated and shade-dried for 10 min: 2.5 cm diameter (~0.7 g) discs for dual-choice assays and 5 cm diameter (~1.5 g) discs for no-choice assays. In the dual-choice test, a treated (T) and an untreated (C, labelled as UT) disc were presented to a single larva, with feeding observed every 3 h or for a maximum of 24 h until ~50% of one disc was consumed. No-choice assays provided only treated discs. Each treatment was replicated 20 times under controlled conditions. Initial and final disc weights were recorded, and the percentage of leaf area consumed was calculated. Mortality from positive controls was corrected using Abbott's formula, with all negative values set to zero. Antifeedant activity was expressed as a percentage, where higher values indicate stronger effects. The antifeedant index formula is:

$$\text{Antifeedant Index} = \frac{(C-T)}{(100-C)} \times 100$$

Sublethal effects on development and biological parameters

Surviving *S. frugiperda* larvae from the no-choice assay were used to assess sublethal effects of the crude botanical extracts on larval development and life cycle progression. Larvae were continuously exposed to treated castor (*R. communis*) leaf discs (diameter=5 cm, weight ≈ 1.5 g), with fresh leaves replaced every 24 h. Daily observations included the weight of the leaves consumed, the weight of the larvae, and the duration of feeding up until the sixth instar. Biological parameters included weight, developmental duration, survival, mortality, emergence, and malformations across larval, prepupal, pupal, and adult stages. Oviposition and full life cycle assessment were not conducted due to the lack of rearing cages and facilities, but the measured parameters provide valuable insights into insect development under controlled conditions. The formulas provided below were used to calculate several biological parameters:

$$\text{Survival/Emergence (\%)} = \frac{\text{Number of (larvae,pupae,adult) survived}}{\text{Total number of (larvae,pupae,adults)}} \times 100$$

$$\text{Mortality (\%)} = \frac{\text{Number of dead (larvae,pupae,adults)}}{\text{Total number of (larvae,pupae,adults)}} \times 100$$

$$\text{Malformed (\%)} = \frac{\text{Number of malformed(larvae,pupae,adults)}}{\text{Total number of (larvae,pupae,adults) emerged}} \times 100$$

Statistical analysis

Data were statistically analyzed and visualized using PAST software version 5.2.2 (Oslo, Norway) and GraphPad Prism version 10.4.2 (San Diego, CA, USA). Lethal concentrations (LC_{30}), along with their 95% confidence limits (CLs) and slope values, were calculated using R software and verified against lower and upper limits using LDP Line software. A normality test was conducted, and descriptive statistics were initially computed. Parametric data were analyzed using one-way analysis of variance (ANOVA), and mean comparisons were performed using Tukey's post hoc test at a significance level of $p<0.05$. Non-parametric data were analyzed using the Kruskal–Wallis test, followed by the Mann–Whitney U test with Bonferroni correction. Spearman's rank correlation was conducted to evaluate the relationship between percent mortality and antifeedant index.

RESULTS AND DISCUSSION

Dose-dependent toxicity

Crude extracts from chili (*C. frutescens*) fruits, madre de cacao (*G. sepium*) leaves, and lemongrass (*C. citratus*) stalks and leaves showed clear dose-dependent toxicity against 3rd instar larvae of *S. frugiperda* (Figure 1). Mortality increased with concentration, with *C. citratus* being the most potent (LC_{30}=51.3 g/L), followed by *C. frutescens* and *G. sepium*. Although their effects were lower than positive control methomyl (LC_{30}=0.00833 g/L), the botanicals displayed gradual but measurable toxicity consistent with prior reports of *C. citratus* essential oils against *S. frugiperda* (Eldesouky et al. 2024). This study also provides the first experimental evidence of sublethal effects from *C. frutescens* and *G. sepium* on *S. frugiperda*. Methomyl, a carbamate insecticide, is highly effective because of its systemic anticholinesterase activity, producing rapid neural overstimulation and mortality (Bird and Drynan 2023). In contrast, these botanicals act more slowly and at higher concentrations.

Feeding deterrence

Feeding bioassays confirmed that the three botanicals also interfere with larval feeding. In dual-choice tests, *C. citratus* caused the strongest feeding deterrence, with larvae consuming only 28.7% of treated leaf discs (Kruskal-Wallis H_1=13.3, $p<0.001$), while *C. frutescens* (H_1=5.67, p=0.018) and *G. sepium* (H_1=4.74, p=0.029) suppressed feeding moderately. However, there was no significant difference among the three botanicals (two-way ANOVA: $F_{2, 57}$=0.269, p=0.076) (Figure 2). In no-choice tests, both *C. citratus* (31.3% consumption; two-way ANOVA: $F_{4, 96}$=6.30, p=0.042) and *G. sepium* (34.8%; p=0.023) significantly reduced consumption relative to the negative control, while *C. frutescens* (38.2%; p=0.124) was less effective. Methomyl-treated leaves had the lowest

consumption in the no-choice test (18.9%; $p<0.001$), but in the dual-choice test, feeding differences were not significant ($H_1=1.02$, $p=0.312$), likely due to rapid larval death rather than true feeding deterrence.

Antifeedant index values which compares larval consumption of treated versus control leaves (Lewis and van Emden 1986) further distinguished deterrence from toxicity: *G. sepium* recorded the highest mean in the dual-choice assay (49.2%) while the positive control recorded the highest mean in the no-choice test (66.4%) (Figure 3). Mortality rates among botanicals remained low (≤15%) compared to methomyl (30%), confirming that suppression was behavioral rather than lethal. These mortality patterns were further supported by correlation analysis, which showed a weak, non-significant negative relationship ($r=-0.26$, $p=0.75$) between the dual-choice antifeedant index and mortality, and a moderate but also non-significant positive association in the no-choice test ($r=0.4$, $p=0.75$). However, given the small sample size and consequently low statistical power, these correlations should be interpreted with caution.

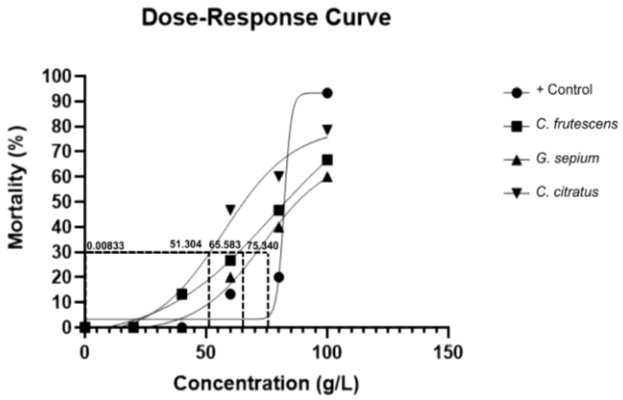

Figure 1. Dose–response mortality of 3rd instar larvae of *Spodoptera frugiperda* exposed to crude extracts of lemongrass (*C. citratus*), chili (*C. frutescens*), and madre de cacao (*G. sepium*), compared with the positive control methomyl. Curves represent fitted probit models, and broken lines show LC_{30} values

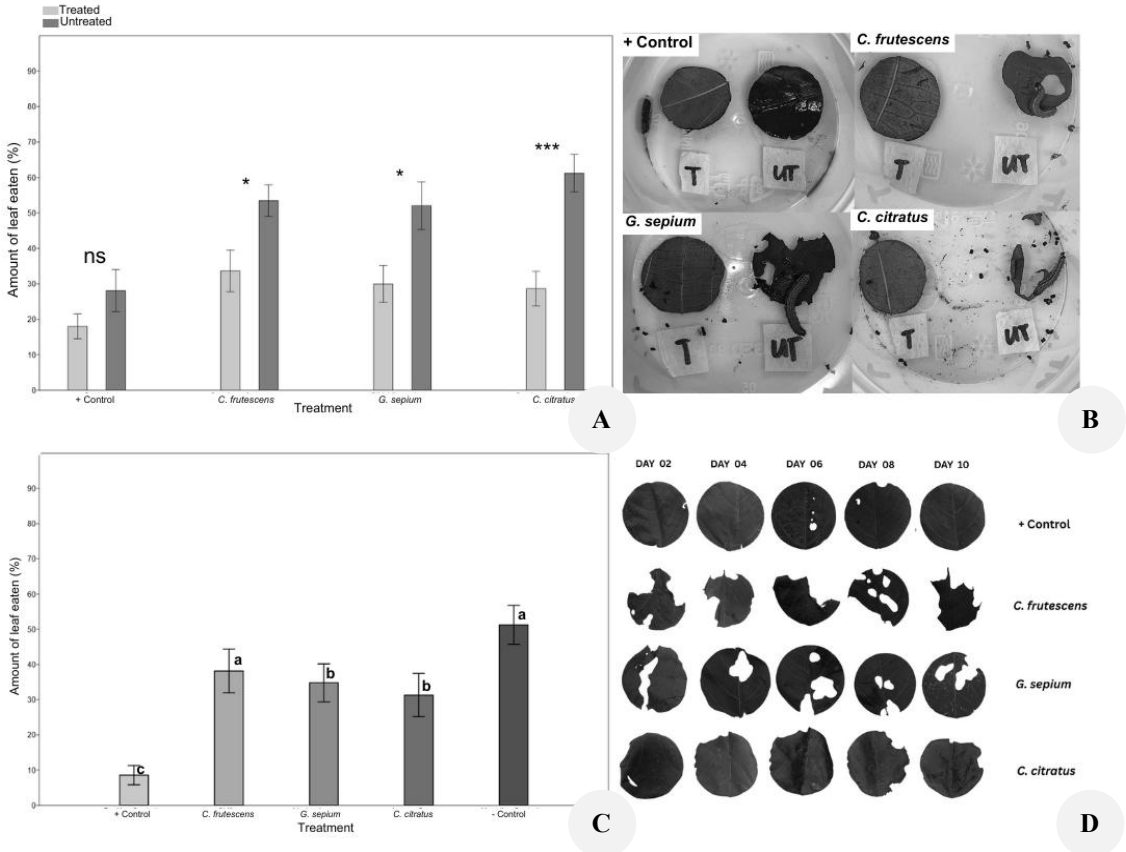

Figure 2. Feeding deterrence of botanical extracts against 3rd instar *Spodoptera frugiperda*. A. Mean percentage of leaf area consumed in a dual-choice assay with LC_{30}-treated and untreated castor leaves and C. No-choice with LC_{30}-treated castor leaves. B. Experimental setup of the dual-choice test and D. Representative feeding activity of larvae on LC_{30}-treated leaves recorded across 10 days, illustrating deterrent effects of botanical extracts compared with controls. Bars show mean ± SEM (n=20). Statistical significance: $p<0.05$(*), $p<0.01$(**), $p<0.001$(***), 'ns': not significant. Treatments sharing the same letter are not significantly different ($p>0.05$)

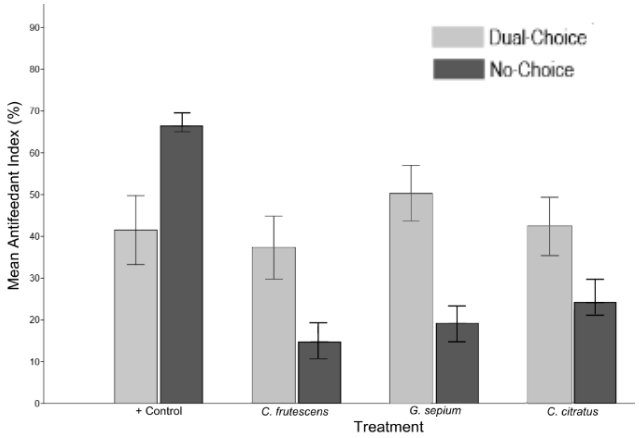

Figure 3. Antifeedant activity of botanical extracts against 3rd instar *Spodoptera frugiperda*. Mean Antifeedant Index (%) calculated from dual-choice and no-choice feeding assays on LC_{30}-treated castor leaves. Bars represent mean ± SEM (n=20). Higher values indicate stronger deterrence

Antifeedants typically act on specific sensory cells and receptors in insects, with associated neurons either preventing initial feeding (deterrent effect), often observed in barrier planting, or reducing further feeding (suppressant effect) as seen in insect sprays, and among the three, *C. citratus* consistently exhibited strong deterrent and suppressant activity in both feeding assays. This outcome resonates with ethnobotanical practices as *C. citratus* is widely used in the Philippines both as a foliar spray and intercrop barrier; its deterrent and suppressant effects observed here validate its field effectiveness (Calumpang et al. 2013), and as effective essential oils and leaf powders have been utilized by local farmers in Nigeria to repel stored-product pests (Folake et al. 2023). *Gliricidia sepium* demonstrated strong deterrence but weaker suppression, suggesting that its role in pest management may be better suited to barrier planting where avoidance is favored. *Gliricidia sepium* has long been planted along rice field margins to reduce tungro virus vectors in the Philippines (Calumpang et al. 2014) and is also associated with higher maize yields in Africa when used as a botanical spray (Kenis et al. 2022). The effectiveness of *C. frutescens* is also evident in Uganda, where it is commonly used to spray crops, illustrating how culturally rooted bio-insecticidal practices are supported by laboratory evidence of feeding deterrence (Tavares et al. 2021). Its widespread use as food, medicine, and bio-insecticide reflects a multifunctional value that goes beyond mere efficacy. Comparable antifeedant efficacy has also been demonstrated under laboratory conditions. For instance, *C. citratus* essential oil shows strong repellency against stored-product pests due to terpenoids such as citral and geranyl acetate (Gvozdenac et al. 2021). Similarly, *G. sepium* and *C. frutescens* extracts have antifeedant effects against closely related species *Spodoptera litura* (Parvathi and Jamil 1999; Movva and Pathipati 2017). These deterrent effects are linked to volatile and bitter-tasting secondary metabolites such as citral in *C. citratus*, capsaicinoids in *C. frutescens*, and coumarins in *G. sepium* that insects detect through olfactory and gustatory cues. Overall, these findings indicate that the three botanicals mainly serve as feeding deterrents with moderate toxicity. Their impacts, although slower, align with farmers' traditional knowledge across different regions, showing that cultural pest management methods are based on practical ecological results.

Development and survival

Prolonged exposure to sublethal concentrations of crude extracts disrupted feeding behavior, growth, and survival of *S. frugiperda*, though effects varied among botanicals.

Developmental parameters

Cymbopogon citratus and *G. sepium* sped up molting, suggesting disruption of normal hormonal regulation. In contrast, *C. frutescens* showed insectistatic (causing increased larval duration) properties, reduced survival to 35%, and caused malformations (Table 1). Prolonged exposure to plant volatiles is known to increase physiological stress and interfere with molting in lepidopterans (Kaur et al. 2023; Idowu and Alabi 2024). Among the three botanicals, *C. citratus* showed the highest survival but was the only one to cause larval deformities, likely through citral-mediated disruption of chitin biosynthesis (Jin et al. 2022). *Capsicum frutescens* insecticidal effects parallels observations in *S. litura*, where phenolic compounds such as vanillic, syringic, chlorogenic, and sinapic acids lead to delayed larval development (Movva and Pathipati 2017); *G. sepium* produced milder effects overall.

Survival rates during the later life stages remained steady, indicating that the larval stage is the most vulnerable to botanicals (Table 2). Studies confirm that botanical effectiveness is highest when used against early folivorous larval stages with chewing mouthparts (Pavela et al. 2025). Disrupting larvae early not only delays their growth but also increases their susceptibility to predators, parasitoids, and botanical pesticide applications, potentially boosting natural biological control. Similar reports show that the larval stage of *S. frugiperda* is highly susceptible to 69 plant-derived extracts, including *Cymbopogon citratus*, which cause mortality, growth suppression, and delayed development (Rioba and Stevenson 2020). For farmers, targeting the larval stage of *S. frugiperda* can lower application frequency, reduce costs, minimize crop losses, and decrease chemical use.

Table 1. Larval duration (days) and survivability (%) of *S. frugiperda* treated with botanical extracts

Treatment	Dose (LC_{30}: g/L)	Duration (days) (Mean ± Sem)	Survival (%)	Malformations (%)
C. frutescens	65.6	7±0.527a	45	0
G. sepium	75.3	4.57±0.327bc	70	0
C. citratus	51.3	4.06±0.213c	80	5
Control (+)	0.00833	6±0.275ab	60	0
Control (-)	0	5.56±0.372ab	90	0

Note: Means (± SEM) with similar letters in the column are not statistically significant

Morphological abnormalities

The botanicals induced prepupal molting failures, malformed pupae, and adults with wing deformities that reduced survival and reproduction. Deformities were most common during the pupal stage (Table 2), when disruption of hormonal regulation and structural reorganization interference led to incomplete development. *Cymbopogon citratus* produced the most malformations overall and was the only extract to induce unique prepupal deformities, highlighting its strong growth-regulating effect. *Capsicum frutescens* caused the highest frequency of pupal malformations and abnormal adult emergence, while *G. sepium* induced fewer but still notable defects. Across its life cycle, *S. frugiperda* experiences stage-specific disruptions from different botanicals: larval feeding deterrence and growth inhibition limit maturity, prepupal deformities caused by *C. citratus* stop pupal formation and metamorphosis, pupal malformations largely induced by *C. frutescens* prevent adult emergence, and adult sublethal effects across treatments reduce longevity, fecundity, and dispersal. Collectively, these abnormalities exert significant ecological impacts that weaken pest populations across generations. Sublethal effects such as delayed growth and deformities, though less immediate than mortality, suppress population growth across generations and strengthen community-based pest management (Figure 4).

Ethnobotanical records across Southeast Asia support the findings of this study, highlighting *Cymbopogon* and *Capsicum* species and *G. sepium* as effective farmer-derived pest control agents. In the Philippines, these plants are traditionally used as insecticides by Ayta, Matigsalug, and Maranao farmers, and similar practices are reported in Indonesia and Vietnam, demonstrating regional relevance (Obico and Ragragio 2014; Dao-Huy et al. 2021; Afrianto et al. 2022; Valdez 2023). Water-based preparations, valued by smallholder farmers for their low cost and ease of use, are comparable to essential oils or ethanol-based extracts reported in prior studies and have significantly affected *S. frugiperda*. Recent laboratory and field studies support these results: *C. citratus* essential oils show strong larvicidal and deterrent effects against *S. frugiperda*, phenolic compounds of *C. frutescens* reduce survival and disrupt larval development, and methanolic extracts of *G. sepium* exhibit antifeedant effects against the closely related *S. litura*, traits that contribute to its effectiveness as an intercrop (Parvathi and Jamil 1999; Movva and Pathipati 2017). These culturally important plants serve dual roles: traditional sources in households and agriculture, and now scientifically proven as effective, affordable, and sustainable pest control agents. By combining traditional knowledge with scientific validation, this study shows that ethnobotanical insecticides are not only effective and environmentally friendly alternatives to synthetic chemicals, but they could also help preserve biodiversity, promote resilience, and support food security across the Philippines and Southeast Asia.

Table 2. Survivability (%) and morphological abnormalities (%) in remaining life stages of *S. frugiperda* treated with botanical extracts

Treatment	Dose (LC_{30}: g/L)	Survival (%)			Malformations (%)		
		Pre-pupae	Pupae	Adults	Pre-pupae	Pupae	Adults
C. frutescens	65.6	45	35	35	0	28.6	14.3
G. sepium	75.3	70	65	65	0	7.69	7.69
C. citratus	51.3	75	70	70	6.25	14.3	7.14
Control (+)	0.00833	60	55	55	0	9.09	0
Control (-)	0	90	90	90	0	0	0

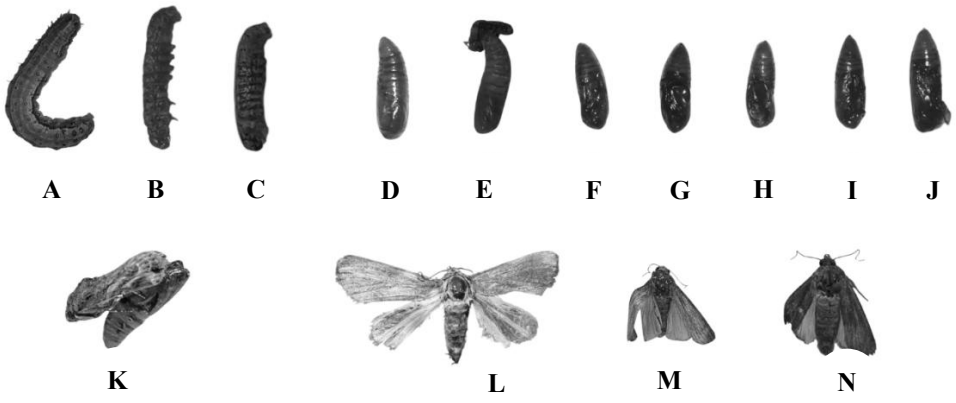

Figure 4. Sublethal effects of botanical treatments on various life stages of the fall armyworm, *Spodoptera frugiperda*. A. Healthy 6th instar larva; B, Darkened, shriveled, and twisted 6th instar larval body with visible prolegs; C. Short, underdeveloped pre-pupa; D. healthy pupa; E. Partially transformed larva with molting failure; F-I. Small, possibly dehydrated or incompletely formed pupae; J. Pupa with a swollen or malformed terminal segment; K. Adult moth that failed to emerge fully and remains attached to the pupal capsule; L. Normal, fully emerged adult; M. Malformed adult with shriveled, undersized wings; and N. Malformed adult with asymmetrical wings, left wing is shorter than the right. Morphological abnormalities are shown for *C. citratus* (B, C, E, J, N), *C. frutescens* (G, H, K), *G. sepium* (I, M), and the positive control, methomyl (F)

Nevertheless, several limitations should be recognized. Laboratory conditions cannot replicate field complexities such as changing temperature, UV degradation, rainfall wash-off, and interactions with natural enemies, which may affect the effectiveness of botanical extracts. Crude extracts can also vary in phytochemical content depending on plant age, season, or growing location, impacting consistency and reproducibility. Potential non-target effects on beneficial insects and soil microbiota were not evaluated and should be addressed in future studies. Moreover, unlike synthetic pesticides that act through rapid toxicity, these plant extracts act more gradually through feeding deterrence, growth disruption, and reduced survival, which suppress pest populations and lower crop damage. These points suggest that the current results are preliminary rather than definitive, but they highlight the long-term potential of botanicals for sustainable crop protection. Future research should focus on field-based validation under farmer-managed conditions, along with phytochemical profiling to identify bioactive compounds, biodiversity, and soil health evaluation. Dose optimization and potential synergistic effects of crude extract combinations, such as lemongrass with chili as a foliar spray or lemongrass with madre de cacao in intercrop systems, should also be explored. Finally, participatory research with farming communities is essential to develop practical, culturally relevant formulations and assess socioeconomic feasibility. Their integration into modern IPM frameworks could further strengthen sustainable pest management strategies. Such approaches will help ensure that botanical insecticides are biologically effective, environmentally safe, and sustainable, while supporting farmers through reduced pesticide costs, improved crop protection, and more resilient income for smallholder households.

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An ethnobotanical study on traditional medicinal uses of *Euphorbia resinifera* by local communities in Beni Mellal-Khenifra, Morocco

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Abstract. *Abd-dada H, Bouda S, Dani S, Bouchari MEH, Adiba A, Haddioui A. 2025. An ethnobotanical study on traditional medicinal uses of* Euphorbia resinifera *by local communities in Beni Mellal-Khenifra, Morocco. Asian J Ethnobiol 8: 230-244. Euphorbia resinifera* O.Berg, endemic to the Beni Mellal-Khenifra region of Morocco, is a culturally and medicinally significant plant now threatened by overexploitation and habitat degradation. This study documented local knowledge, uses, and conservation perceptions through surveys with 515 respondents across five provinces. Socio-demographic data (age, gender, education, residence) and traditional knowledge were analyzed using descriptive statistics, principal component analysis (PCA), and Pearson correlations. Results revealed that knowledge is concentrated among older, rural, and less formally educated populations, while younger and urban respondents showed limited awareness. The latex and stems were the most cited parts, primarily used in treating digestive disorders, skin infections, and diabetes. PCA highlighted strong associations between education level, age, and knowledge distribution. Respondents also reported declining availability of *E. resinifera*, attributing it to unsustainable harvesting and habitat loss. This study demonstrates the erosion of ethnobotanical knowledge alongside ecological threats to *E. resinifera*. Safeguarding this heritage requires integrated strategies, including awareness campaigns, sustainable harvesting practices, and in situ and ex situ conservation. Documenting traditional uses not only supports biodiversity management but also provides a basis for future pharmacological validation.

Keywords: Beni Mellal-Khenifra, ethnobotanical survey, *Euphorbia resinifera*, medicinal plant, Morocco

INTRODUCTION

For millennia, humans have relied on plants not only as nourishment but as vital healing tools. From ancient civilizations to modern societies, plants have alleviated pain, treated illnesses, and promoted well-being, with medicinal knowledge transmitted across generations (Reid et al. 2018; Matole et al. 2021). Even in the 21st century, despite pharmacological advancements, plant-based traditional medicine remains integral to healthcare in many regions, especially in developing nations with limited access to modern medical systems (Nargawe et al. 2023; Khoja et al. 2024; Dalamagka 2024). Morocco, with its diverse Mediterranean landscapes and unique bioclimates, is a biodiversity hotspot hosting thousands of plant species, many endemic or rare (Ghanmi et al. 2011). Of North Africa's 7,000 documented plant species, 4,200 occur in Morocco, including approximately 537 endemics and 1,625 classified as rare or threatened (Benabid 2000; Attouiti 2002). Among these botanical treasures, aromatic and medicinal plants (AMPs) hold profound cultural, ecological, and socio-economic significance. They serve as cornerstones of traditional medicine and potential drivers of sustainable development in rural communities.

One such species, *Euphorbia resinifera* O.Berg, exemplifies the intersection of ecological importance, traditional knowledge, and modern scientific interest. A succulent member of the Euphorbiaceae family, *E. resinifera* is native and endemic to Morocco's Atlas Mountains, thriving predominantly in the Beni Mellal-Khenifra region (Benabid 2000; Fennane et al. 2007). Characterized by its spiny, cactus-like stems that form dense shrubs up to 2 meters in diameter, the plant produces vibrant yellow flowers in late spring, which sustain local bee populations and yield high-quality therapeutic honey (Figure 1) (Abd-dada et al. 2023). Beyond its ecological role as a keystone species in pre-forest ecosystems (Benabid 2000), *E. resinifera* has been revered for centuries for its medicinal latex, known historically as "euphorbium." Ancient texts describe its use as a potent laxative, blistering agent, and antidote for snakebites (Agrawal and Konno 2009), while Moroccan traditional healers have long employed it to manage diabetes, treat severe skin conditions, and address ailments ranging from cancer to parasitic infections (Errajraji et al. 2010; Farah et al. 2014; El Alami et al. 2016). Modern research has begun to validate these uses, identifying diterpenes within the latex with analgesic, antioxidant, antibacterial, and anticancer properties (Talbaoui et al. 2020; El Idrissi et al. 2021).

Despite its cultural and therapeutic value, *E. resinifera* faces mounting threats that jeopardize its survival. Anthropogenic pressures, including overharvesting, habitat fragmentation from agriculture and urbanization, wildfires,

and fungal diseases, have led to alarming population declines (Taha et al. 2024). Compounding these challenges is the gradual erosion of traditional knowledge, as younger generations drift away from ancestral practices and environmental degradation accelerates. The loss of this species would not only disrupt ecosystems but also sever a living link to Morocco's ethnobotanical heritage, underscoring the urgent need for conservation strategies that balance ecological preservation with community needs.

This study concentrates on the Beni Mellal-Khenifra region, a hub of biodiversity and traditional medicine, to document the ethnobotanical uses of *E. resinifera* by local communities. By engaging with indigenous knowledge holders, the research aims to catalog the plant's applications in treating ailments, its preparation methods, and its socio-cultural importance. Such an approach not only respects the expertise of local populations but also offers essential insights for sustainable management. The findings are intended to guide conservation policies that protect *E. resinifera* while supporting rural livelihoods through ethical harvesting and value-added products like medicinal honey. Moreover, this work underscores the plant's potential as a model for integrating traditional wisdom into modern healthcare and biodiversity conservation frameworks.

In a world increasingly struggling with biodiversity loss and the marginalization of indigenous knowledge, the case of *E. resinifera* serves as a microcosm of broader challenges and opportunities. Preserving this species requires a holistic approach-one that recognizes the interdependence of ecological health, cultural heritage, and economic resilience. By combining scientific research with community-driven stewardship, this study aspires to contribute to a future where Morocco's medicinal plants continue to thrive as symbols of natural wealth and human innovation.

MATERIALS AND METHODS

Presentation of the studied region

Located in the center of the kingdom of Morocco, the Beni Mellal-Khenifra Region was established following the 2015 territorial reorganization. This new entity comprises five provinces: Azilal, Beni Mellal, Fquih Ben Salah, Khenifra, and Khouribga (Figure 2). It includes 19 circles, 16 urban communes, and 119 rural communes, covering 28,374 km² (4% of the nation's territory). Four dominant landscapes characterize the region: plains, mountains, foothills, and the phosphate plateau (HCP 2019).

The region's geographical position creates climatic diversity, ranging from humid mountainous zones to semi-arid plains. Overall, it experiences a continental climate, with very cold winters and very hot summers. Landscape variability influences temperature and precipitation, with an average temperature of 18°C (ranging from 0°C to over 40°C) and annual precipitation between 100 mm (arid areas) and 600 mm (humid areas). Mountainous areas above 1,000 meters receive seasonal snowfall (HCP 2017).

According to the 2024 General Population and Housing Census (RGPH), the region's population is 2,525,801, with 50.8% urban residency (below the national average of 62.8%). Its population density is 58.8 inhabitants/km², below the national average of 83.64 (HCP 2024).

Ethnobotanical surveys

Date, location, and duration of the survey

The study was conducted from 1 February 2024 to 9 April 2024 across all five provinces of the Beni Mellal-Khenifra region. Interviews with participants typically lasted between 20 and 40 minutes.

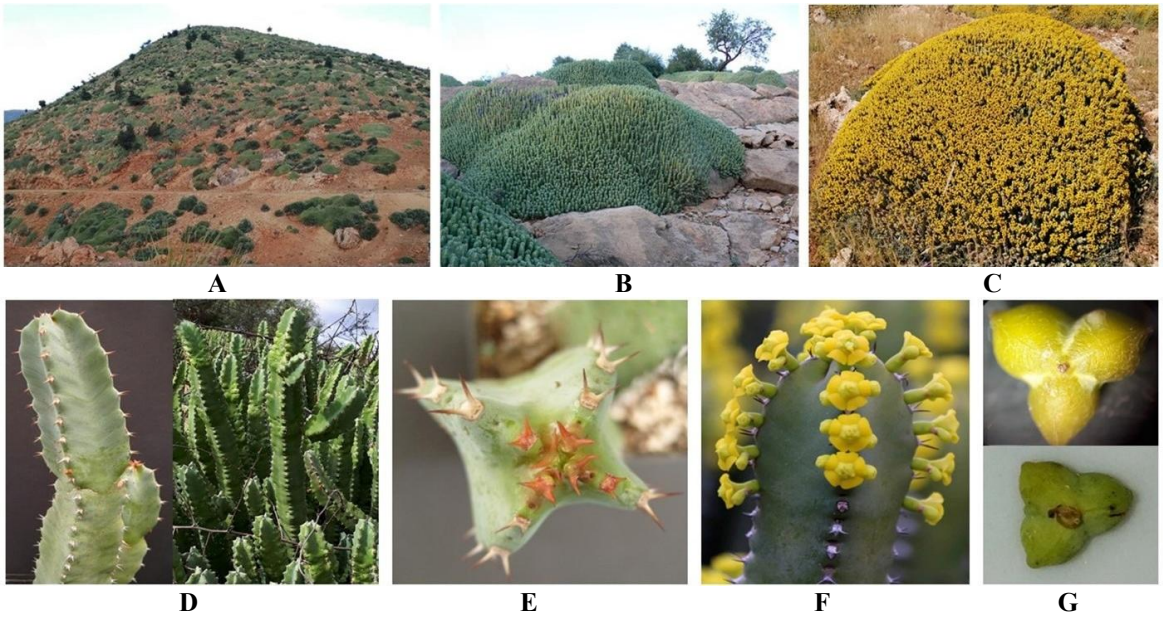

Figure 1. Constituents of the studied medicinal plant. A. *Euphorbia resinifera* population; B. Bush without flowers; C. Bush with flowers; D. Stems; E. Spines; F. Flowers; G. Fruit (Abd-dada et al. 2023)

Tools and procedures for data collection

Before conducting fieldwork, investigation sites within the study area were mapped. Data were collected through face-to-face interviews and discussion groups using semi-structured questionnaires and direct questioning. The questionnaire consisted of two parts: the first focused on participant details (age, sex, marital status, educational level, province of residence, language, and income), while the second gathered information on the medicinal plant (*E. resinifera*) used by respondents to treat or cure diseases.

Sampling and data processing

The sample was prepared using a non-proportional stratified probability (random) sampling method (Godron 1971), divided into zones, covering cities, villages, agglomerations (Douar), and weekly markets in the study region. Sampling was based on ecological factors (climate, soil, altitude), the presence of the study plant, and population distribution. Within the study area, 53 urban and rural zones were selected as the most representative. This selection prioritized populations that use medicinal plants, particularly those who utilize *E. resinifera* (herbalists, traditional practitioners, plant gatherers, healers, and others). Interviewees were first informed of the study's purpose to secure their consent. They were interviewed in Amazigh or Arabic dialects, depending on their language, to document local knowledge on the plant's use for treating various diseases (Table 1).

Table 1. Distribution of survey areas in the study region

Provinces of Beni Mellal - Khenifra region				
Beni Mellal	**Azilal**	**Khenifra**	**Fquih Ben Salah**	**Khouribga**
Beni Mellal (Municipal)	Azilal (Municipal)	Khenifra (Municipal)	Fquih Ben Salah (Municipal)	Khouribga (Municipal)
El Ksiba (Municipal)	Demnate (Municipal)	M'rirt	Ouled Zmam	Bejaad
Kasba Tadla (Municipal)	Imi n'Ifri	Elkbab	Souk Sebt	Tachraft
Zaouiat cheikh (Municipal)	Ait Abbas	Ouaoumana	Ouled Ayad	Oued Zem
Taghzirt	Ait M'Hamed	Tighassaline	Khalfia	Oulad Abdoune
Dir El Ksiba	Ouaouizeght	Aguelmam Azegza	Béni Oukil	Lagfaf
Ait Oum El Bekht	Tanant	Kahf Nssour	Elbradia	
Ighram Laalam	Ouaoula	Oum Rabiaa	Dar Ould Zidouh	
Naour	Ait Atab		Had Boumoussa	
Aghbala	Foum Jemaa			
Sidi Jaber	Bine Elouidane			
Ouled Yaich	Bzou			
Moudj	Ouzoud			
Ouled M'Barek	Afourar			
	Timoulilt			
	Isseksi			

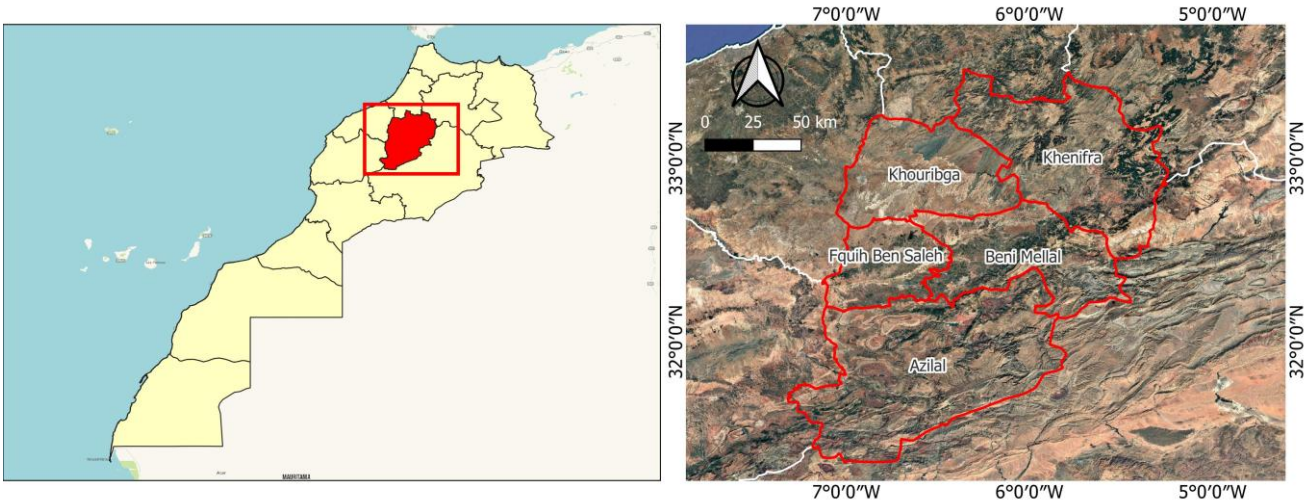

Figure 2. Geographical location and municipal division of Moroccan Beni Mellal-Khenifra Region (HCP 2017)

Using stratified random sampling (Kahouadji 1986), samples were formed in each of the 53 zones and combined to constitute the overall sample of 515 individuals. The number of surveyed individuals varied across zones depending on the use of the medicinal plant *E. resinifera*. Participation in the study is unique, with each person agreeing to complete the questionnaire only once. The process was anonymous and prevented individual identification. Those who had never used this plant for therapeutic or other purposes, as well as transients from regions outside Beni Mellal-Khenifra, were excluded from the survey. The questionnaire was administered to all indigenous persons who agreed to participate and committed to answering honestly.

The collected data were entered and analyzed using Microsoft Excel 2016. Data analysis employed simple descriptive statistical methods: quantitative variables are described using the means, and qualitative variables were described using frequencies and percentages.

To explore the relationships between diseases treated with *E. resinifera* and the socio-demographic characteristics of the informants, we used two statistical methods: Principal Component Analysis (PCA) and Pearson correlation. We also examined how much each variable contributed to the main components in the PCA. Pearson's correlation coefficient (r) was used to measure the strength and direction of the relationships between variables. Only moderate to strong correlations ($r>0.5$ or $r<-0.5$) were considered in the interpretation. Both analyses were conducted using the statistical software OriginPro 2023 (OriginLab Corporation, Northampton, MA, USA).

RESULTS AND DISCUSSION

The ethnobotanical study made it possible to collect several information related to the interviewee and the uses of the studied plant.

Use of the studied medicinal plant according to the characteristics of the interviewees

According to age

The use of the studied plant (*E. resinifera*) was widespread among all respondents, with the highest prevalence (33.2%) observed in individuals aged 50-60 years. However, Lower rates were recorded for the 40-50 age group (26.6%) and those over 60 (13.8%). Use was minimal (1%) among the youngest informants (<20 years old) (Table 2). A cumulative 47% of users over 50 years old indicated a significantly higher reliance on this plant. These results indicate that, in the Beni Mellal-Khenifra region, knowledge of the plant's properties and uses depended on long-term experience and trust in traditional medicine, as respondents retained ancestral knowledge transmitted orally. Knowledge of medicinal plants is typically acquired through long accumulated experience and generational transmission. However, this transmission is increasingly precarious (Anyinam 1995). Therefore, there is a marked lack of interest in phytotherapy and a loss of knowledge about medicinal plants. This can be attributed to a general sense of mistrust, particularly among youth, who favor modernization over traditional practices. These findings align with prior studies on Moroccan medicinal plant use (Benkhnigue et al. 2010; Salhi et al. 2010; Benlamdini et al. 2014; El Hafian et al. 2014).

According to sex

The investigation of the local population (515 individuals) showed that both men and women were engaged in traditional medicine. However, sex-based distribution showed a slight predominance of women overall (266 users of *E. resinifera*, representing 51.7% of the study population) compared to men (249 respondents, 48.3%) (Table 2). This disparity may stem from women's proactive role in maintaining familial health, their multifaceted use of plants, household responsibilities, and adherence to traditional practices. Specifically, women primarily ensure family well-being and healthcare during illnesses. These findings align with prior ethnobotanical studies at the national level, including those by Benkhnigue et al. (2010) in Mechraâ Bel Ksiri, El Hafian et al. (2014) in Agadir-Ida-Outanane prefecture, and others (Salhi et al. 2010; Mandal et al. 2021; Mantuan and Sannomiya 2024), which consistently highlight women's greater familiarity with and reliance on traditional phytotherapeutic knowledge.

According to the family situation

In the study area, *E. resinifera* is used significantly more by married individuals (68.5%) than by single individuals (22.7%), while the remaining categories (divorced, widowed) account for 8.7% (Table 2). These results align with findings from prior studies (Benkhnigue et al. 2010; Hafsé et al. 2015; Chraibi et al. 2018). This trend may reflect married individuals' reliance on the plant to reduce material expenses associated with purchasing synthetic drugs. The same finding was reported by Fatima et al. (2015) in their study of medicinal plants used to treat respiratory infections in Morocco's Middle Atlas.

According to the school level

The analysis of the collected data showed that the majority of *E. resinifera* users are illiterate (32%). However, the proportion of plant users with primary education is relatively higher (31.8%) than those with secondary education (20.8%), while individuals with university-level education use this endemic plant significantly less (15.3%) (Table 2). These results are comparable to those obtained by Lahsissene et al. (2009) and Fatima et al. (2015). This suggests that the use of *E. resinifera* as a medicinal plant declines as educational attainment increases.

According to locality and language

The results showed that most users of this endemic Moroccan plant in the study area reside in Azilal Province (37.3%), while 11.5% belong to Khenifra Province, and 14% to Khouribga Province. In contrast, Fquih Ben Salah and Beni Mellal Provinces exhibited similar proportions (19 and 18.3%, respectively). Consequently, 54% of the

population are Amazigh speakers, compared to 46% Arabic speakers (Table 2).

Regarding living environment, the majority of respondents using *E. resinifera* reside in villages and Douars (43.9 and 35.5%, respectively), whereas only 20.6% of the surveyed population lives in urban areas (Table 2). Factors such as limited informational, geographical, and economic access to modern healthcare; inadequate distribution of healthcare staff in isolated localities; mistrust of synthetic products; the preference for "bio" alternatives and socio-cultural habits collectively explain the widespread reliance on medicinal plants like *E. resinifera* for treatment in the Beni Mellal-Khenifra region.

According to income/month (MAD: Moroccan Dirham)

In our study, 59.8% of the population using the studied plant earn less than 1,500 MAD/month, while 31.8% of respondents have incomes ranging between 1,500 and 5,000 MAD, and only 7.8% earn between 5,000 and 10,000 MAD (Table 2). Indeed, medications are expensive, whereas medicinal plants can be freely harvested from nature, explaining why income significantly shapes perceptions of plant use in traditional medicine. These results align with those of Benlamdini et al. (2014), who documented medicinal plants used in traditional phytotherapy by the Eastern Moroccan High Atlas population. The findings indicate that reliance on the studied plant increases as informants' monthly income decreases.

Therapeutic practices

The choice between traditional medicine and modern medicine is firstly

Among the 515 interviewed individuals who use both herbal and modern medicine, the data indicate a higher prevalence of modern medicine users. Specifically, 80.8% (416 individuals) in this region prefer modern medicine as their first choice, while only 19.2% (99 individuals) primarily rely on traditional medicine. Of the latter group, 8% chose traditional medicine primarily for its effectiveness, 50% due to lower costs, 35% for reasons of acquisition, and only 7% due to perceived inefficacy of modern drugs. Among modern medicine users, 41% adopted it for its precision, 12% for its effectiveness, and 47% due to concerns about plant toxicity, such as that of *E. resinifera* (Figures 3.A and 3.B). The toxicity of certain plants, particularly *E. resinifera*, has made residents of the Beni Mellal-Khenifra region cautious, aligning with this study's findings. The reported values here are lower than those from Chraibi et al. (2018) for *Mentha pulegium, Mentha piperita,* and *Pelargonium graveolens* in the Taounate region and from Chaachouay (2020) for medicinal plants used in phytotherapy in the Rif (northern Morocco).

Vernacular name of E. resinifera *in the studied region*

The plant classification system employed in this study is based on responses provided by the interviewees. A single medicinal plant may have multiple Arabic and Amazigh vernacular names, depending on the region (Bellakhdar et al. 1997). In this survey, three vernacular names for the plant *E. resinifera* were identified: zeggoum, daghmouss, and tikiwt. Among the respondents, 43% referred to the plant as zeggoum, 20% as daghmouss, and the remaining 37% used the term tikiwt. These names align with those documented by Bellakhdar et al. (1997).

Therapeutic and cosmetic uses of the plant

The information gathered on the local therapeutic and traditional uses of *E. resinifera* revealed that 94.6% of its applications are therapeutic (487 respondents), 13.8% corresponds to cosmetic use (71 respondents), and 6.2% to other purposes (32 respondents). These overlapping responses indicate that the plant is utilized by respondents for both therapeutic and cosmetic applications.

Table 2. Summary of interviewees' socio-demographic data

Characteristics	Number (Total=515)	Percentage (%)
Age		
<20	5	1.0
20-30	82	15.9
30-40	49	9.5
40-50	137	26.6
50-60	171	33.2
>60	71	13.8
Sex		
Male	266	51.7
Female	249	48.3
Family situation		
Single	117	22.7
Married	353	68.5
Others (Divorced, widowed)	45	8.7
School level		
None	165	32.0
Primary	164	31.8
Secondary	107	20.8
University	79	15.3
Province of residence		
Khenifra	59	11.5
Beni Mellal	94	18.3
Azilal	192	37.3
Fquih Ben Salah	98	19.0
Khouribga	72	14.0
Locality		
City	106	20.6
Village	226	43.9
Douar	183	35.5
Language		
Arabic	237	46.0
Amazigh	278	54.0
Income / Month (MAD)		
<250	154	29.9
250-1,500	154	29.9
1,500-5,000	164	31.8
5,000-10,000	40	7.8
>10,000	3	0.6

Parts used of the plant

According to the ethnobotanical survey, the latex was identified as the dominant part used in the preparation of remedies derived from *E. resinifera* in the study area (75.5%; 389 respondents), followed by the stem (33.6%), flower and seeds (17.7%), fruit (15.1%), and underground part (6.8%), respectively. In contrast, the spines were reported as the least frequently used component (1.4%; 7 respondents). These results are comparable to those reported nationally by Benkhnigue et al. (2010) (Figure 4).

The preference for latex and stem was attributed to their easy availability, ease of harvesting, and simplicity in remedy preparation. Additionally, these parts contain the majority of secondary metabolites (Appendino et al. 2010). Notably, they have been reported to possess anti-inflammatory, antibacterial, antifungal, and anticancer activities (Farah et al. 2014; Talbaoui et al. 2020).

Techniques and the moment of harvest of the plant studied for traditional uses

The results of the survey conducted with our informants show that 42.3% of the population employs mechanical harvesting techniques, while only 40.8% purchase the plant, and 16.9% use manual methods. These findings indicate significant exploitation pressure on the region's flora, which could lead to undesirable ecological consequences. Regarding the timing of harvest in the study region, the ethnobotanical survey revealed that 94.56% of respondents (447 individuals) reported year-round harvesting of the plant. However, a small minority (5.44%) stated that harvesting occurs seasonally. This result indicates that the plant is perennially available in traditional remedies used in the Beni Mellal-Khenifra region.

State of the plants used

According to the ethnobotanical survey, fresh plant is predominantly used (53%) compared to dried plants (31%) (Figure 5). In contrast, the use of treated plant material (combined with other medicinal ingredients such as honey, maceration in water or olive oil) is the least common, accounting for 16%. The study conducted by Abdurhman (2010) shows that 86% of preparations utilize fresh plant material. These results may reflect the plant's availability in the study region and the perceived efficacy of fresh medicinal plants in traditional treatments.

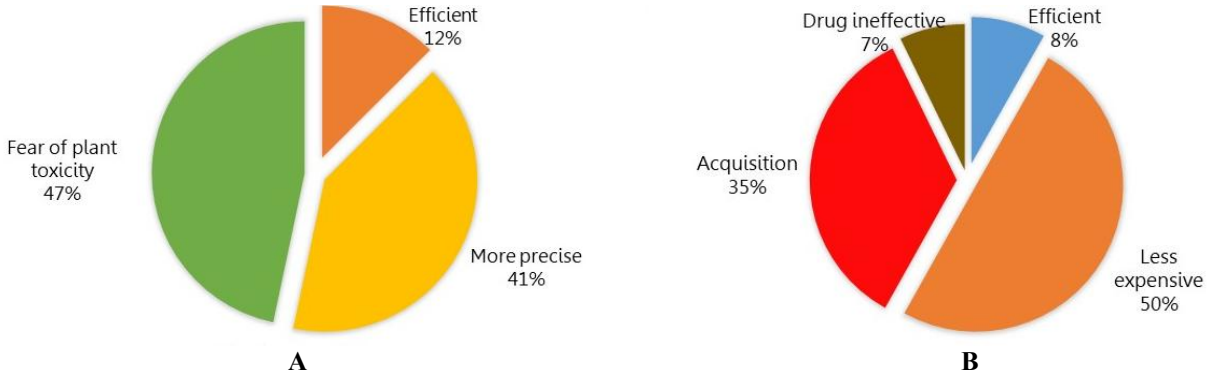

Figure 3. Percentage of different reasons for respondents' medication preferences. A. Modern medicine; B. Traditional medicine

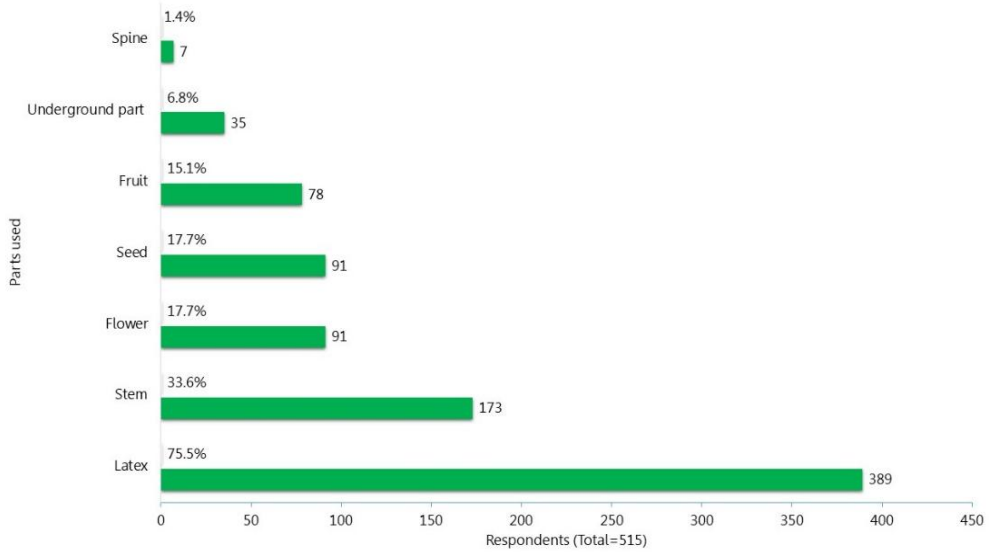

Figure 4. Distribution of *E. resinifera* use according to plant parts

Drug preparation

According to the recorded recipes (Figure 6), the plant is prepared alone (10% of respondents) or combined with other plant species (11%). In contrast, combinations with honey accounted for the highest proportion 43%, while other combinations represented 36%. Notably, recipes incorporating honey were the most prevalent, likely to neutralize the sharp (bitter) taste or mitigate the toxicity of the plant's latex during remedy preparation. These results contrast sharply with those of El Rhaffari and Zaid (2002), who, in a similar survey conducted in southeastern Morocco (Tafilalet), found that 85.3% of recorded recipes utilized the plant alone, with only 14.7% combined with other ingredients.

Preparation methods of the studied plant

Given the plant's toxicity, preparation methods in the study area are highly specific to avoid poisoning (Figure 7). Our study found that latex mixed with warm water and honey is the most common preparation in traditional remedies derived from the plant, accounting for 30% of applications. Other methods, such as decoction in water, tea, or milk, represent 25%. Depending on the treated ailment, interviewees utilize powdered dried plant parts (cumulative 18%), while stems without latex combined with juice or ground aerial parts mixed with honey also account for 18% cumulatively. The frequent use of honey in Beni Mellal-Khenifra traditions- especially in areas where the plant naturally grows- explains the 9% of remedies incorporating *E. resinifera* honey. This aligns with findings from the Azilal and Beni Mellal Atlas regions by El Alami et al. (2020). Furthermore, ethnobotanical surveys in other Moroccan regions further indicate that most respondents prepare remedies via decoction (Salhi et al. 2010; Fatima et al. 2015; Slimani et al. 2016; Bourhia et al. 2019), underscoring the widespread exchange of knowledge on medicinal plant use among Moroccan communities.

Dose used

In the study region, the surveyed population informed us that remedies based on *E. resinifera* are administered in varying doses: 72% by spoonful, 23 % by pinch, and 5% by handful (Figure 8). This absence of standardized dosing practices among the local population of the Beni Mellal-Khénifra region may pose adverse health risks. These results partially align with findings from Benkhnigue et al. (2010) in the Mechraâ Bel Ksiri region.

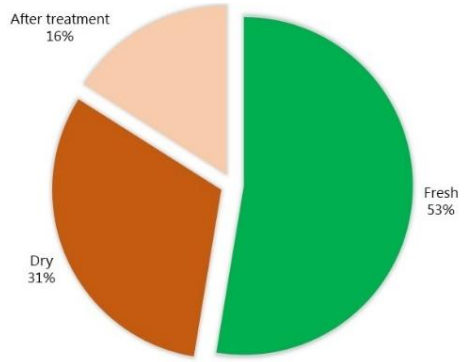

Figure 5. Use of the plant according to its state

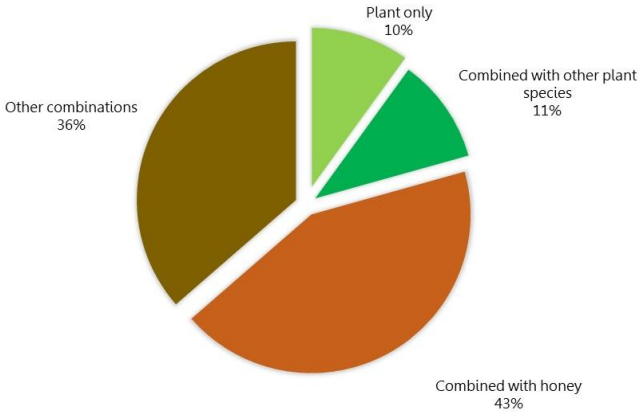

Figure 6. Proportion of species used alone and mixed

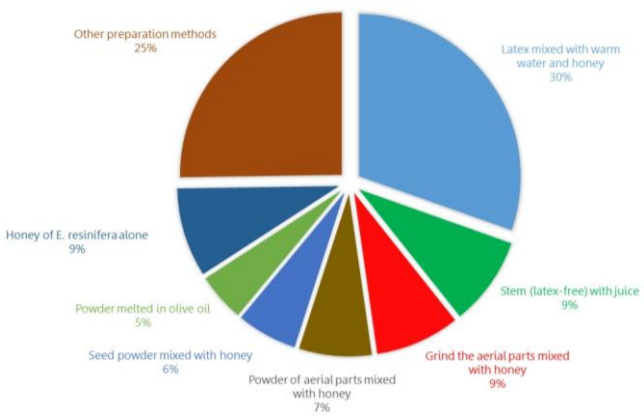

Figure 7. Methods of preparation of plant (%)

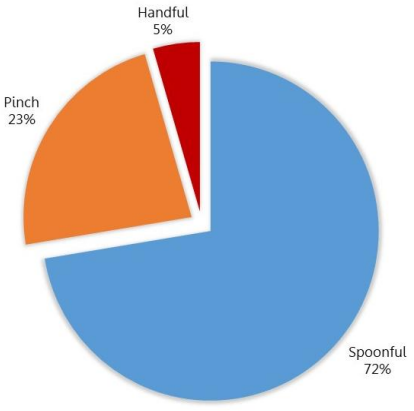

Figure 8. Use of the plant according to dose precision

Method of administration

According to the surveys, the most common form of administration is oral (52%). However, external application (17%) is primarily used for wound healing, wound disinfection, and insect bite treatment. The remaining 31% utilize both administration modes (Figure 9). The predominance of oral administration for remedies based on the studied medicinal plant aligns closely with ethnobotanical studies conducted across North Africa (El Hafian et al. 2014; Chermat and Gharzouli 2015; El Hajli et al. 2024).

Treatment duration

The duration of treatment varies significantly depending on the individual and the treated condition. Analysis of Figure 10 shows that treatment with *E. resinifera* until cure is achieved is most common (77%), followed by one-week duration (15%). Finally, one-month and one-day treatment durations account for 7% and 1%, respectively. These results are in agreement with those of Chaachouay et al. (2020), who reported that treatment with medicinal plants until cure was predominant (46.6%).

Source of information

Regarding the source of information through which respondents learned about the plant's uses, 50% reported relying on advice and experiences from their immediate social circle (family and friends) who use it as a remedy for specific illnesses. This highlights the intergenerational transmission of traditional practices. 35% obtained their information from a herbalist "Achabe", while 15% self-sourced knowledge by consulting traditional medicine texts, watching television programs, or drawing on personal experience due to the plant's prevalence in their environment (Figure 11). These results align with studies by Benkhnigue et al. (2010) in the Mechraâ Bel Ksiri region and El Yahyaoui et al. (2015) in Laayoune Province.

Diagnostic methods

Data analysis resulted in Figure 12, which shows that in the study areas, 39% of indigenous self-diagnosed (201 interviewees), followed by 33% diagnosed by a doctor, and 17% by an herbalist. Finally, diagnoses through other methods accounted for the remaining 11%.

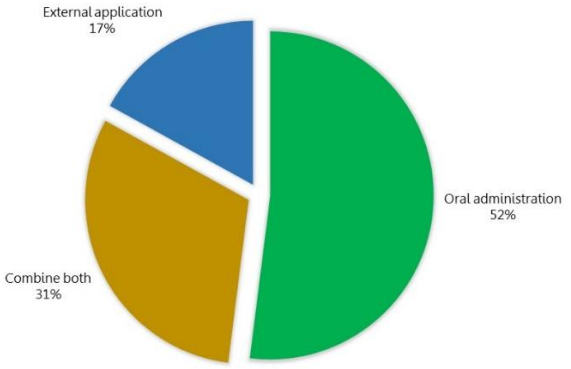

Figure 9. Frequency of different methods of administration of remedies based on the plant *E. resinifera*

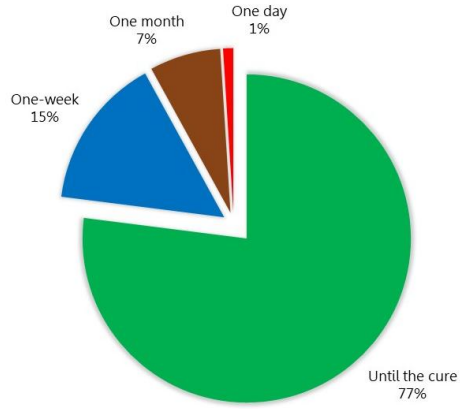

Figure 10. Frequency of different durations of use of remedies based on the plant studied

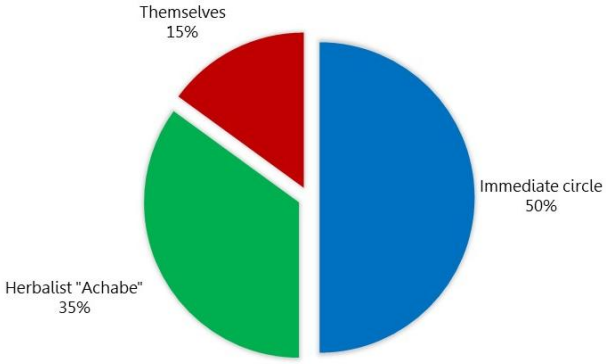

Figure 11. Distribution of *E. resinifera* users according to the origin of information

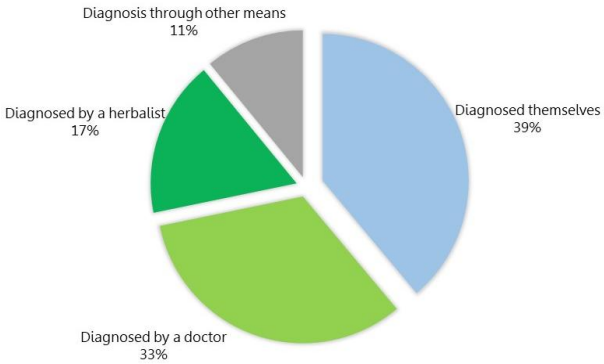

Figure 12. Proportion of actors responsible for disease diagnosis

Diseases treated by *E. resinifera* plant

In humans

The ethnobotanical survey revealed that the plant *E. resinifera* is primarily used in humans to treat type 2 diabetes (58%; 299 respondents) and digestive disorders (54.2%). Its applications for cancer treatment include 19% for female genital cancers, 25.40% for breast cancer, 28.30% for skin cancer, and 34.40% for cancers such as colon, lung, uterine, leukemia, and oral cancers. Local populations also use the plant to treat snake bites and scorpion stings (39.80%), warts (42.5%), female genital tract cysts (28.7%), toothaches (49.10%), and hair care (8.20%). Additional uses are detailed in Table 3. These findings on the therapeutic uses of *E. resinifera* align with phytochemical studies. Research indicates that extracts from various parts of *E. resinifera* exhibit significant therapeutic potential, rivaling synthetic chemicals and antibiotics in treating infectious diseases (Hanane et al. 2014; Samouh et al. 2019; Belhaj et al. 2020; Talbaoui et al. 2020). Among respondents, 51% believe *E. resinifera* effectively cures the treated conditions, 48% consider it improves health outcomes, and 1% distrust its efficacy (Figure 13). These results correlate with studies by Zeggwagh et al. (2013) in Fes, Chraibi et al. (2018) in Taounate, and Chaachouay (2020) in the Moroccan Rif.

Contrasting with Mediterranean studies by Fortini et al. (2016), Chiocchio et al. (2024), Patti et al. (2025), in Italy, Saive et al. (2018), Zidane et al. (2020) in French, and Emre et al. (2021) in Turkey, which primarily document generalized applications of multiple plant taxa for digestive, respiratory, and dermatological conditions, our results demonstrate that *Euphorbia resinifera* is distinctively employed against a spectrum of highly specific pathologies. Notably, it is extensively utilized in managing type 2 diabetes (58% of respondents), diverse malignancies (reported in up to 34.4% of applications—including female genital cancers (19%) and genital tract cysts (28.7%), envenomation (39.8%), and oral pathologies (49.1%). These applications, particularly for oncological, toxicological, and dental conditions, remain undocumented in the comparative literature, underscoring the distinctive ethnopharmacological role of this endemic Moroccan species within its regional healing traditions.

In animals (pets)

The results show that *E. resinifera* is also utilized in animals (pets) to treat specific ailments, depending on the animal type. For poultry, goats, cattle, and other animals, 29, 28, 25, and 11% of respondents, respectively, reported using this plant to treat certain diseases. However, 7% of the respondents do not use the plant (Figure 14.A). Among users of *E. resinifera*, perceived treatment efficacy varied: 50% reported complete cure and 41% observed health improvement, dependent on the animal species and disease treated, while 9% deemed it ineffective (Figure 14.B). These findings underscore the need to better understand the true efficacy of this medicinal plant in veterinary applications, as well as potential risks linked to side effects. A more rigorous research approach is required to evaluate its safety and therapeutic potential in veterinary medicine systematically.

Main diseases treated by E. resinifera *honey in humans*

Euphorbia resinifera honey is widely used for therapeutic purposes; analysis of survey results from this study demonstrates its efficacy in treating a broad spectrum of ailments (Table 4). A 69.70% of respondents (359 individuals) use this honey to treat digestive diseases, and 59% to treat cancers. It is also effective against respiratory diseases (57.50%). Local populations further utilize this melliferous plant's honey for reproductive system diseases (34.40%) and intoxications (32.80%). Similarly, *E. resinifera* honey is used to treat throat infections (29%) and skin disorders (24.10%). Additionally, respondents report its use for headaches (20.60%), weakness, and jaundice (8.70%). These findings corroborate studies by Errajraji et al. (2010), Kuehn (2018), Boutoub et al. (2020), and Benjamaa et al. (2020). Also, the honey of this species is utilized for cosmetic purposes as hair and skin care (El Alami et al. 2016).

Table 3. Diseases treated using the medicinal plant *E. resinifera* in the Beni Mellal-Khenifra region

Diseases treated	Number of respondents (Total=515)	Percentage %
Type 2 diabetes	299	58.0
Type 1 diabetes	261	50.7
Digestive disorders	279	54.2
Toothaches	253	49.1
Warts	219	42.5
Snake bites and scorpion stings	205	39.8
Inflammation (general)	203	39.4
Other conditions	204	39.6
Skin inflammation	197	38.3
Cancers (colon, lung, uterus, leukemia, oral)	177	34.4
Goiter	153	29.7
Female genital tract cysts	148	28.7
Skin cancers	146	28.3
Breast cancer	131	25.4
Poisonings	128	24.9
Female genital tract cancer	98	19.0
Respiratory diseases (influenza, asthma, allergies)	61	11.8
Hair care	42	8.2
Abortifacient	17	3.3
Paralysis	14	2.7

Table 4. Main diseases treated by *E. resinifera* honey in humans in the Beni Mellal-Khenifra region

Diseases treated	Number of respondents (Total=515)	Percentage %
Digestive diseases	359	69.7
Cancers	304	59
Respiratory diseases (influenza, asthma, allergies, etc.)	296	57.5
Reproductive system diseases	177	34.4
Intoxications	169	32.8
Throat infections	149	29
Skin disorders	124	24.1
Headaches	106	20.6
Weakness, and jaundice	45	8.7

Side effects and toxicity of the E. resinifera *plant*

A question was posed to respondents to assess their awareness of potential side effects associated with *E. resinifera*. Results show that 19% reported observing no adverse effects from using this medicinal plant. However, 75% noted mild side effects related to its use (Figure 15.A). Only 6% believed the plant causes toxicity post administration. Additionally, the present study reveals widespread awareness of the plant's toxicity: 81% answered "Yes" to the question, "Is this plant toxic?" while 19% responded "No" (Figure 15.B). This awareness likely explains the low reported toxicity (6%) among users. Respondents who acknowledged toxicity also emphasized the plant's efficacy, asserting it addresses limitations of modern medicine. Collectively, these findings reflect strong confidence in herbal medicine within the studied population.

Statistical analysis: Principal Component Analysis (PCA) and Pearson correlation

Relationships between diseases treated with E. resinifera *and the socio-demographic characteristics of the informants*

The result of Principal Component Analysis (PCA) showed that the first two principal components accounted for 72.5% of the total variance. The first component (PC1) explains 51.13% of the total variation, and the second component (PC2) explains 21.37%. PC1 mainly separates long-term and internal diseases, while PC2 helps identify treatments for external and short-term problems (Figure 16).

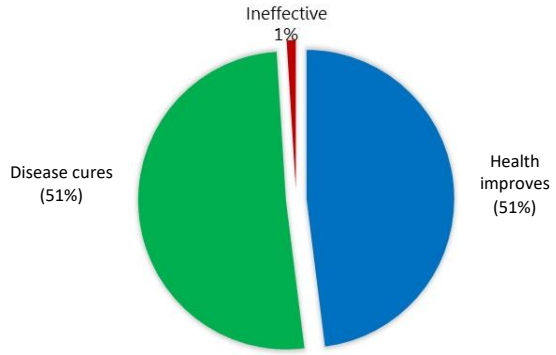

Figure 13. Results of improvement observed after phytotherapy in humans

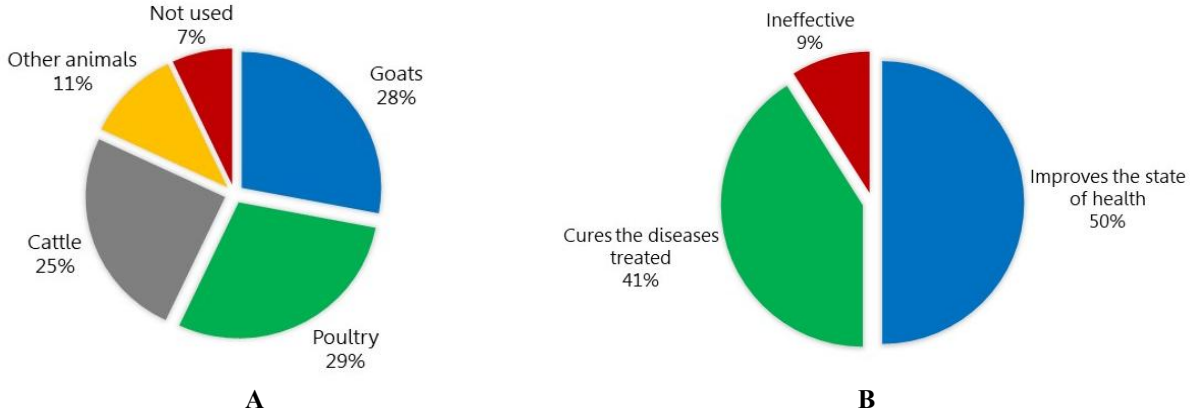

Figure 14. A. Diseases treated in pets; and B. Results after treatment

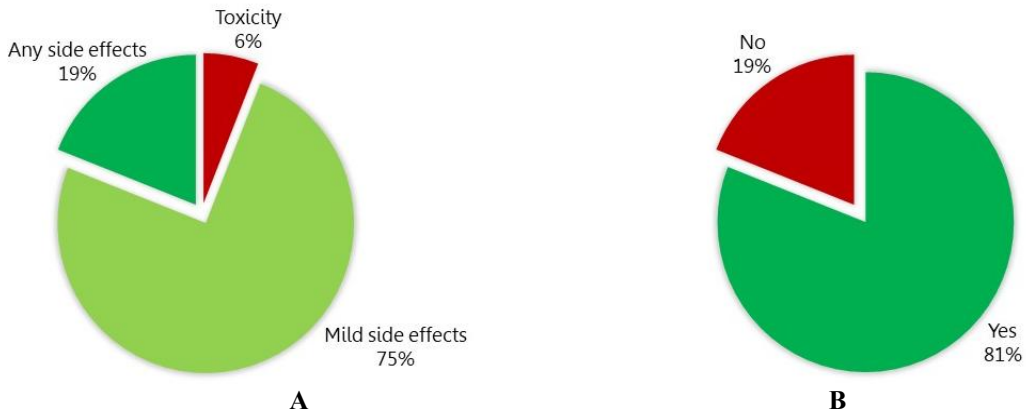

Figure 15. A. Percentage of side effects; and B. Information on the toxicity of the plant studied

The result shown in Figure 16.A demonstrates that diseases like type 2 diabetes, type 1 diabetes, and digestive disorders had high positive values on PC1. This suggests that *E. resinifera* is mostly used to treat these chronic diseases. These conditions are often related to long-term health problems such as blood sugar imbalance and stomach issues, and the plant might be used for its anti-inflammatory or hypoglycemic properties. On the other hand, diseases such as toothaches, warts, and snake bites and scorpion stings had high positive values on PC2. These are more acute or external problems, which may be treated with direct applications of the plant. This shows that *E. resinifera* is also used for fast, traditional treatments in urgent or painful conditions. Moreover, some diseases had low or negative values on both PC1 and PC2, such as breast cancer, female genital tract cancer, paralysis, and abortifacient use. These low values mean that *E. resinifera* is not often used for these types of conditions, or that the use is limited to a few individuals or specific communities.

When we compare this information with the socio-demographic characteristics, we see interesting relationships (Figure 17). People aged under 30 had higher values on PC2, showing that younger people are more likely to use the plant for quick treatments like skin problems or toothaches. In contrast, people aged 40 to 60 had higher values on PC1, meaning they tend to use the plant more for chronic diseases like diabetes or digestive disorders. In addition, Men were more associated with PC1, suggesting they use the plant more for internal or chronic health issues. Women, on the other hand, had higher values on PC2, meaning they may use the plant more for external conditions or reproductive health. In terms of education, people with primary and secondary school education were more associated with PC2, while those with university education were more associated with PC1.

This may reflect differences in knowledge or preferences in how the plant is used. Looking at the regions, people from Khenifra and Beni Mellal were more related to PC1, which means that in these areas, the plant is mostly used for long-term diseases. People from rural areas (villages and douars) contributed to both PC1 and PC2, showing that the rich and varied traditional knowledge is rich and varied in these regions. Language also played a role. Both Arabic and Amazigh speakers were associated with PC1, showing that both groups use *E. resinifera* for chronic conditions, and that this traditional knowledge is shared across ethnic groups. Moreover, income had an important effect. People with lower incomes (<250 MAD) contributed more to both components, meaning they rely more on the plant for different treatments. People with higher incomes had lower contributions, which may indicate less dependence on traditional medicine and more access to modern healthcare.

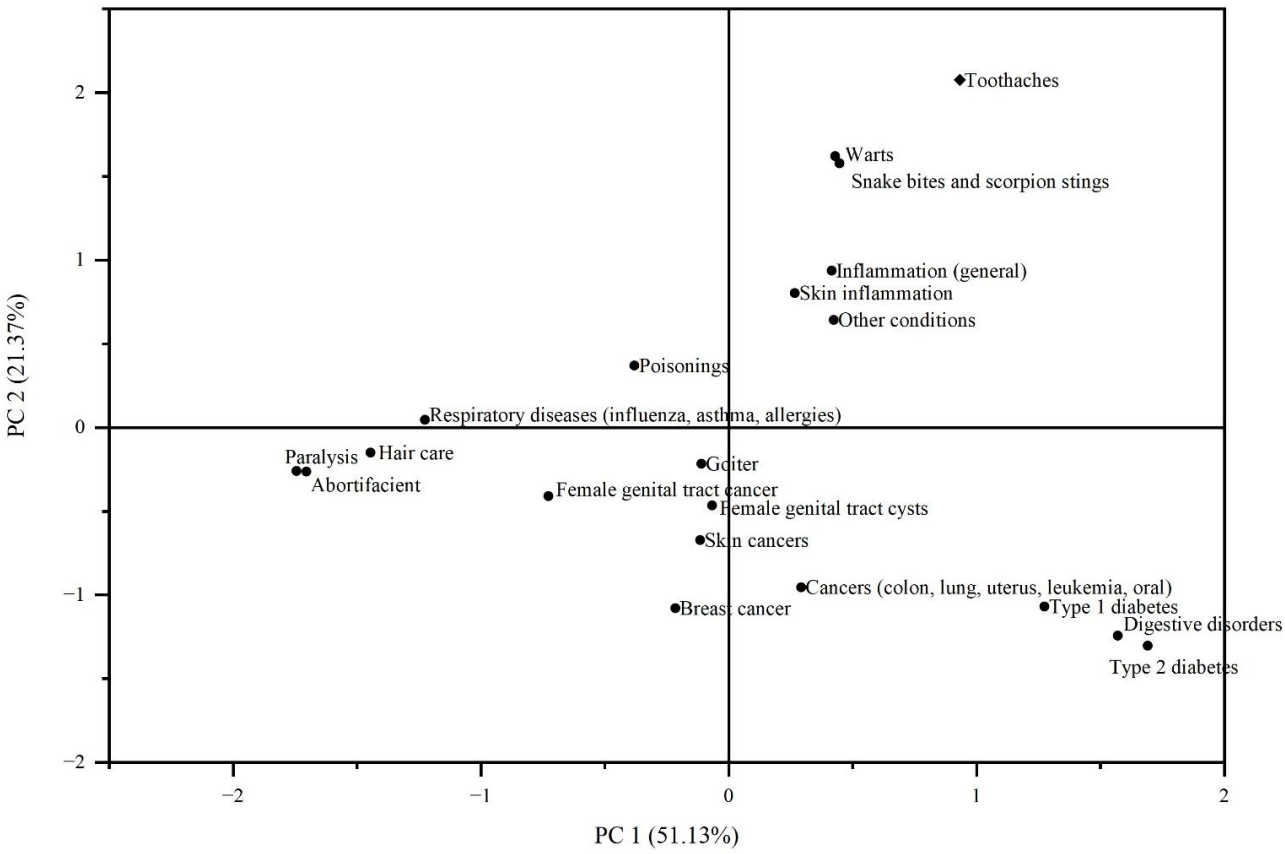

Figure 16. Principal Component Analysis (PCA) score plot of diseases treated by *E. resinifera* in the Beni Mellal Khenifra region

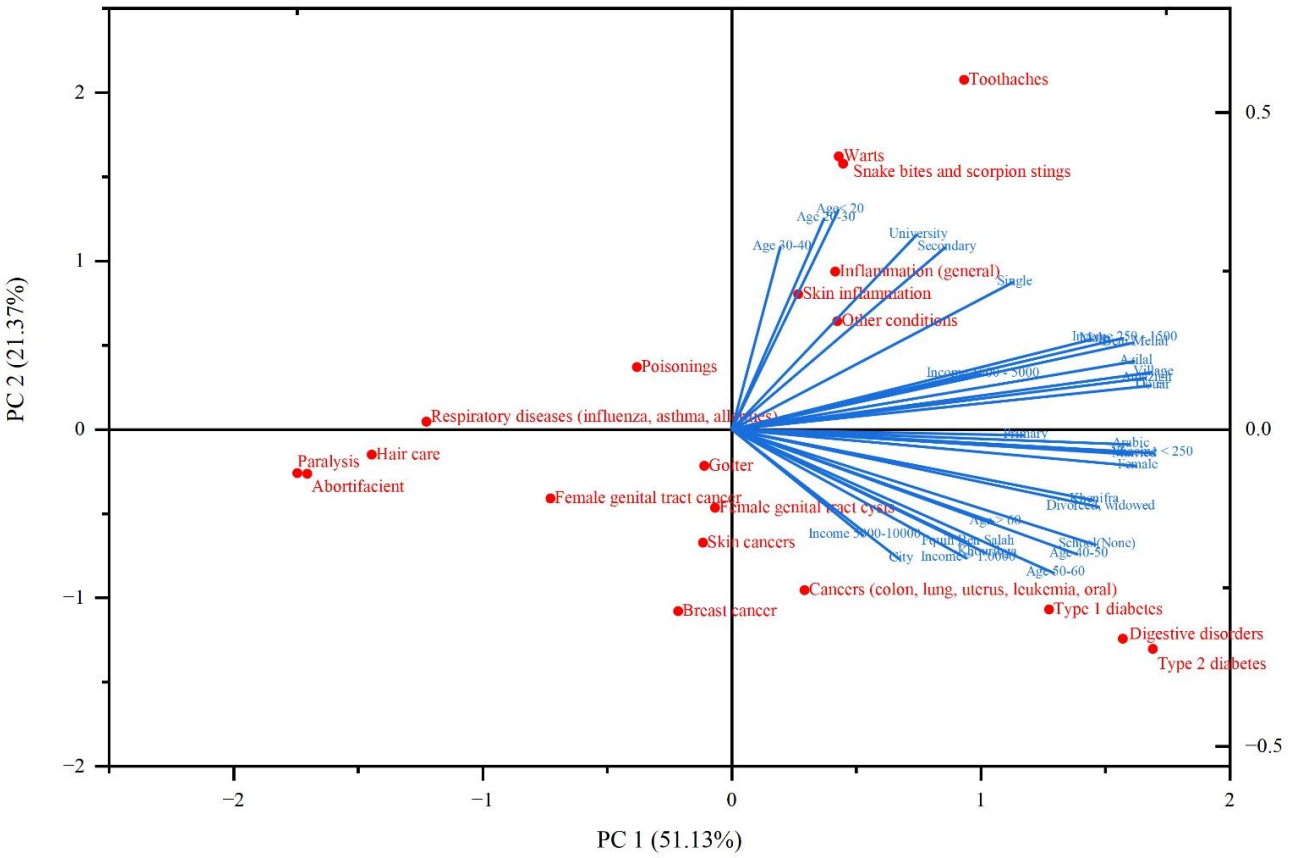

Figure 17. PCA biplot of the relationship between diseases treated with *E. resinifera* and respondents' socio-demographic characteristics

The study revealed that the PCA shows that *E. resinifera* is mostly used for metabolic and digestive diseases, especially by middle-aged women in rural areas. It is also used for acute problems like toothaches and bites, especially by young, educated people. The use of the plant depends on several social factors, such as age, gender, education, place of residence, language, and income. These factors influence how people use and value traditional medicine. Future studies should focus on confirming the plant's effectiveness for the most common diseases, like diabetes and toxicological problems, to connect traditional knowledge with modern science.

Correlation analysis between the different parts of E. resinifera *used in traditional medicine and the socio-demographic characteristics of respondents*

The correlation matrix shows important relationships between socio-demographic characteristics and the use of specific parts of *E. resinifera* among interviewees in the Beni Mellal-Khenifra region. Strong correlations ($|r|\geq 0.5$; $p<0.05$) indicate that age, gender, income, location, and education all influence how this plant is used in traditional medicine. These patterns reflect both the preservation of traditional knowledge and the impact of modern social and economic changes on ethnobotanical practices (Figure 18).

Use of plant parts and demographic influences. Latex shows opposite trends depending on the group. There is a negative correlation with young people (Age<20: r=-0.55), but a positive one with high-income participants (Income>10,000 MAD: r=0.55). This suggests that younger generations are less involved in using latex, while wealthier individuals may use it for more specialized or commercial purposes. Also, the stem is strongly linked to urban residents (City: r=0.61) and Arabic-speaking users (r=0.41), showing how urbanization influences traditional medicine use. Furthermore, flowers are mostly used by poorer people (r=0.68), those in rural areas (Village: r=0.67; Douar: r=0.61), and women (r=0.57). Married and divorced or widowed people also use flowers more (r=0.63 and 0.74), which shows that women play an important role in family health care.

In addition, fruits are mostly used by older people (Age 40-50: r=0.75; Age 50-60: r=0.76) and wealthier users (r=0.61), especially in the Khouribga (r=0.55) and Fquih Ben Salah (r=0.50) Provinces. This could be because older people have more knowledge, and wealthier people can afford the less common parts. Spines are linked to education (Secondary: r=0.50; University: r=0.54), which may mean educated people are more open to new or less traditional uses. On the other hand, seeds and underground parts don't have many strong links, but seeds are closely related to flower use (r=0.69), which suggests they may be used together.

Socio-demographic patterns of variation. Age makes a big difference. Young people use latex and fruit less (r=-0.55 and -0.32), while older people still use fruit (r=0.53) and stem (r=0.38). Gender and marital status also matter: flowers are more commonly used by women and those who are married or divorced, which fits with women's role in family healthcare. Income creates two groups: poorer people use flowers and latex because they are easier to get, while richer people use fruit and latex for more specific treatments. In addition, the place of living and language also affect plant use. Rural people prefer flowers, showing they keep more traditional knowledge. City dwellers use stems more, showing adaptation to modern life. Arabic speakers use stems (r=0.41) and fruits (r=0.58) more than Amazigh speakers, which may show a mix of cultures. In different provinces, people use the plant in different ways: Beni Mellal and Azilal prefer flowers (r=0.58 and 0.60), while Khouribga uses more fruits (r=0.55). Education encourages the use of spines (r = 0.50-0.54), but people without schooling use them less (r=-0.18). So, education can help people learn new uses but may also cause traditional ways to fade.

This study identified three main points from the analysis. First, traditional knowledge is not being passed down to young people, while older individuals still use the plant in more traditional ways. Second, income influences which plant parts are utilized—poor people use what is easy to find, whereas wealthier individuals use more specialized or commercial parts. Third, the location and culture of people affect how they use the plant-rural residents retain flower-based knowledge, urban residents tend to use stems more, and educated people explore new uses like spines.

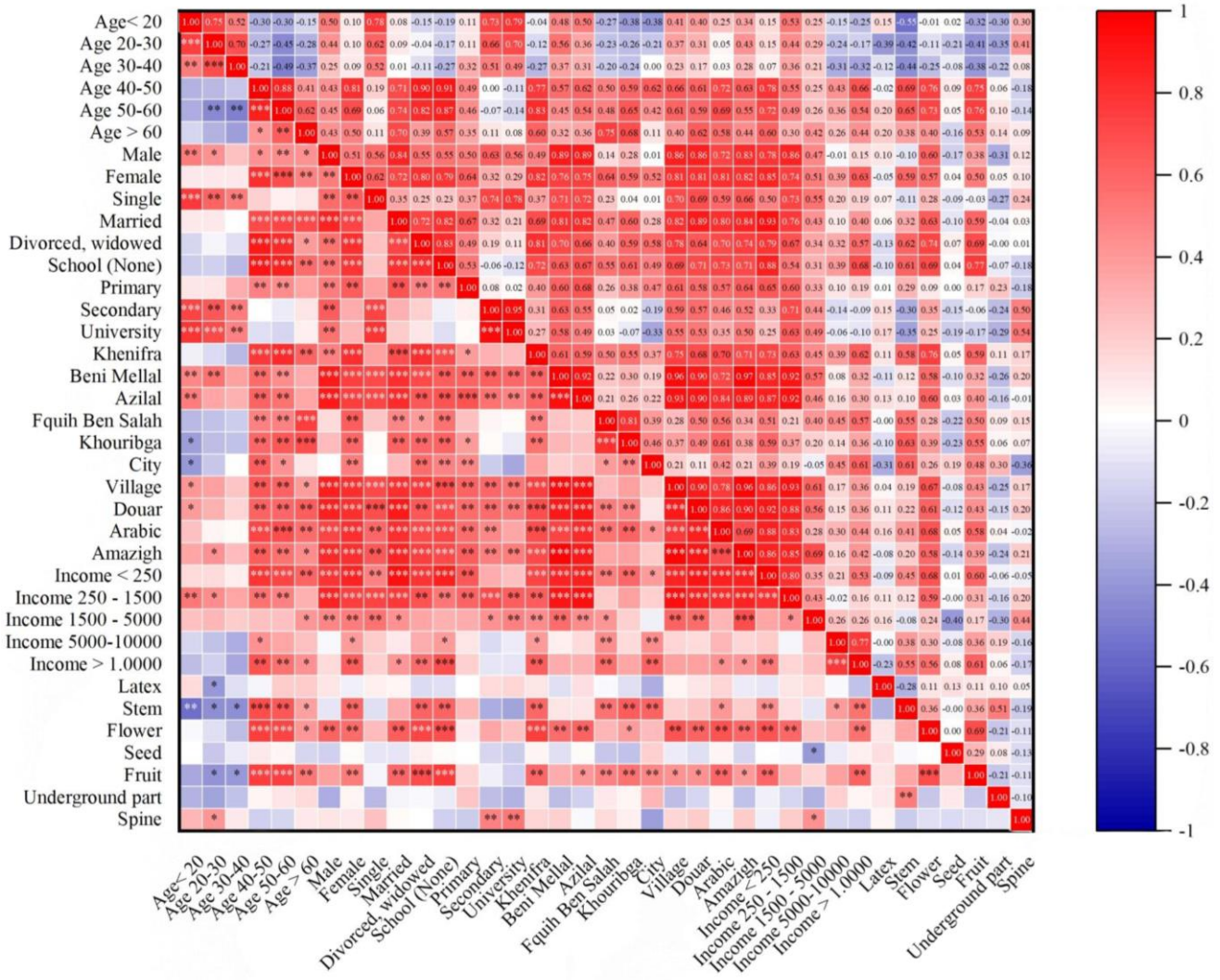

Figure 18. Correlation matrix between respondents' socio-demographic characteristics and parts of *E. resinifera* used in traditional applications

In conclusion, the ethnobotanical survey in the Beni Mellal-Khenifra region underscores the extensive traditional knowledge of local populations regarding the medicinal use of the endemic *E. resinifera*. Notable for its regional prevalence and therapeutic efficacy, the species' documented properties are empirically validated by chemical and pharmacological studies. Utilization frequency correlates with demographics: older individuals exhibit greater familiarity than younger generations, and women hold a slight edge in medicinal knowledge, reflecting intergenerational expertise transmission. Latex and stems are the primary plant parts used, prepared with consideration of dosage and toxicity. The population demonstrates significant awareness of toxicity risks (81%), yet employs the plant widely for treating Type 2 diabetes, digestive disorders, cancers, and diverse ailments via its honey. Preserving this heritage requires safeguarding knowledge transmission to future generations. Rising demand for phytotherapy now threatens both biodiversity and cultural heritage. Safeguarding *E. resinifera* requires urgent in situ and ex situ conservation, regulated harvesting, and measures to ensure ecological sustainability. At the same time, its documented pharmacological potential supports continued bioprospecting for novel therapeutics. Integrating this knowledge into health education and cultural programs will help preserve ancestral traditions while promoting responsible, sustainable use.

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Cultural ethnobotany and urban biodiversity in an eco-friendly *Rakhi*-making initiative in Rajasthan, India

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Abstract. *Jain V. 2025. Cultural ethnobotany and urban biodiversity in an eco-friendly* Rakhi-*making initiative in Rajasthan, India. Asian J Ethnobiol 8: 245-257.* Festivals are integral to the culturally rich Indian subcontinent. Rakshabandhan (*Rakhi*), celebrated on *Shravani Purnima*, is a unique traditional Indian festival symbolizing the bond of trust between siblings, where sisters tie a sacred thread on their brother's wrists. To promote eco-consciousness and the use of sustainable materials in traditional crafts, an eco-friendly *Rakhi*-making competition was organized in August 2024 by the Department of Botany, Government Meera Girls College, Udaipur, Rajasthan, India, in which 23 female students (mean age = 20.65 years) participated. An ethnobotanical survey through participant interviews and field observation was conducted to document the plant-based materials used. A total of 53 plants (13 wild and 40 cultivated) belonging to 28 families were employed to prepare various *Rakhi* by the participants. Among these, 44 Dicotyledon, 8 Monocotyledon, and 1 Gymnosperm plant were observed. Fabaceae was the most represented family, followed by Apocynaceae, Poaceae, Asteraceae, and Euphorbiaceae. Floral parts were maximally utilized, followed by seeds, leaves, fruits, roots, and stems. The highest Relative Frequency of Citation (RFC) was recorded for *Vigna radiata* (0.35), *Oryza sativa* and *Rosa* spp. (0.30 each), indicating easy accessibility of these plant materials. Notably, *Platycladus orientalis* and *Pistacia vera* used in this competition are listed as Near Threatened in the IUCN Red Data List, highlighting the need for conservation efforts. This initiative showcases the creative integration of traditional knowledge and sustainability and suggests that such competitions can inspire ethnobotany-based entrepreneurship, while fostering ecological awareness and cultural values among students.

Keywords: Cultural ecology, festival, non-timber forest products, urban biodiversity, urban ethnobotany, youth innovation

INTRODUCTION

Festivals, as part of human culture, reflect creativity, spirituality, and unity. They are celebrated for faith and religious purposes and also for marking change in seasons, the country's important days, or to showcase the art, craft, music, dance, or the tradition of a particular community. They act as catalysts for social cohesion and community engagement, create employment opportunities, and boost tourism (Owano and Nyamanga 2024). Rituals embedding traditional wisdom are an important part of many of the festivals and have long been recognized as powerful conduits of cultural expression and identity formation.

In India, several traditional festivals are celebrated across the entire country, among which Diwali, Holi, and *Rakhi* (Rakshabandhan) are prominent ones (Lata et al. 2022). *Rakhi* is celebrated every year on *Shravani Purnima*, i.e., full moon day of Shravan month (as per the Hindu calendar), which usually falls in August on different dates as per the English calendar. This festival is known for the bonding between a brother and sister, where a sister ties a thread in the form of a beautiful *Rakhi* (*Raksha sutra*) on the wrist of his brother in demand of protection. Brother, vows on this occasion to take care of his sister and protect her from evil forces. This act is not merely ceremonial; it exemplifies how rituals reinforce social ties and serve as living embodiments of cultural meaning and emotional identity (Karle et al. 2025). Usually, *Rakhi* is prepared from the cotton/silk-cotton or synthetic fiber thread, plastic, any metal (silver/gold/brass/aluminum/copper/iron), and other decorative items. Fifteen days before the occurrence of the festival, stalls containing different varieties of *Rakhi* are displayed in the markets of both rural and urban areas. The *Rakhi* is often costly and, unfortunately, non-biodegradable, raising environmental concerns.

Ethnobotany is the study of all kinds of relationships existing between plants and people including use of plants for various cultural traditions, festivals, and rituals (Jigme and Yangchen 2022; Lata et al. 2022; Ma et al. 2024). In fact, valuable botanical insights could be obtained through ethnobotanical investigations of festival-related practices within specific communities (Franco and Robin 2011). For example, Lata et al. (2024) documented the use of 47 plants for the celebration of Fulaich (festival of flowers) by Kinnaura tribes in Himachal Pradesh, India. Mukarromah et al. (2024) reported the use of 27 Angiosperm plants in 10 traditional festivals celebrated in three villages of Surakarta City, Central Java Province, Indonesia. Moreover, traditional ecological knowledge is also shown in various rituals and daily cultural practices (Ma et al. 2024). Ethnobotanical studies are therefore, essential to find out that how human beings interact with plants and what roles are played by plants in human life.

Rajasthan is the largest state of India as per area, with 13.48% scheduled tribal population of its total population (Population Census Data 2025). Udaipur city, situated in

South Rajasthan, is a well-known tourist city on the world map, situated at a latitude of 24.5854° North and a longitude of 73.7125° East. Various traditional fairs and festivals are vibrantly celebrated all year round in Udaipur city, for example, *Holi, Basoda, Dasha Mata, Gangaur, Rakhi, Hariyali Amavasya, Navratri, Diwali*, etc. Ethnobotanical investigations to some of these have revealed that a number of plants are related to these festivals in different forms. Kunwar and Jain (2021) recorded the use of 23 Angiosperm plants in traditional fairs organized on *Hariyali Amavasya* and *Sakhiya Somwar* in Udaipur, Rajasthan. However, the use of plants in various cultural expressions that formulate the culture-based man-plant relationships is hitherto less explored among the ethnobotanical studies carried out so far in Rajasthan, India. The studies reporting different plants used for various arts and crafts are also scanty.

In view of all these, traditional festivals can be harnessed as powerful platforms for promoting eco-conscious, culturally rooted, and sustainable practices. As *Rakhi* is a well-known traditional Indian festival celebrated by using several synthetic items for making the sacred thread, an attempt was made to promote eco-consciousness among the youth to celebrate it sustainably. With this in mind, for the first time, an eco-friendly *Rakhi* competition was organized on Friday, 16 August 2024, in view of the forthcoming *Rakhi* festival (19 August 2024), for the students affiliated to the Department of Botany, Government Meera Girls College, Udaipur, Rajasthan, India. Earlier, such competitions were held in Punjab, Maharashtra, and New Delhi, India. In this competition, girls were given a task to prepare and bring an eco-friendly *Rakhi* (made from eco-friendly materials, especially plants), which was displayed in the Department of Botany for faculty members of all Departments of the College. The location map from where the students collected the plants to prepare *Rakhi* is given in Figure 1. The objective of this study was to document the plant diversity that young people used to prepare *Rakhi*, as well as to explore the culture-based relationships between people and plant that emerged from the eco-friendly *Rakhi* competition.

MATERIALS AND METHODS

An ethnobotanical survey of the above-mentioned eco-friendly *Rakhi*-making competition organized at the Government Meera Girls College, Udaipur, India, was carried out through observation and interview of participants (n=23) on 16 August 2024.

Procedural details

Prior informed consent was obtained from the participants before taking the interview and photographs. Also, the objectives and process of this study were explained to them before conducting the survey. The competition was conducted with prior permission of the institute, but there was no need for ethical approval to conduct such a study. Interviews were taken from 23 girls who participated in the competition, with code numbers given to them. To keep the privacy, the first and middle names of the participants are abbreviated in Table 1. All the students were asked to provide a list of plant materials that they used to prepare the *Rakhi*. Queries, for example, from where did they get the various plant materials, from where did they get the idea of preparing such a kind of *Rakhi*, what motivated them to use a particular plant for *Rakhi*, the local name of the plant used if any, the preference of wild v/s cultivated plants for making *Rakhi*, etc., were also asked to them. Digital documentation of the eco-friendly *Rakhi* prepared by them was also done through capturing images; some of which have been shown in Figure 2.

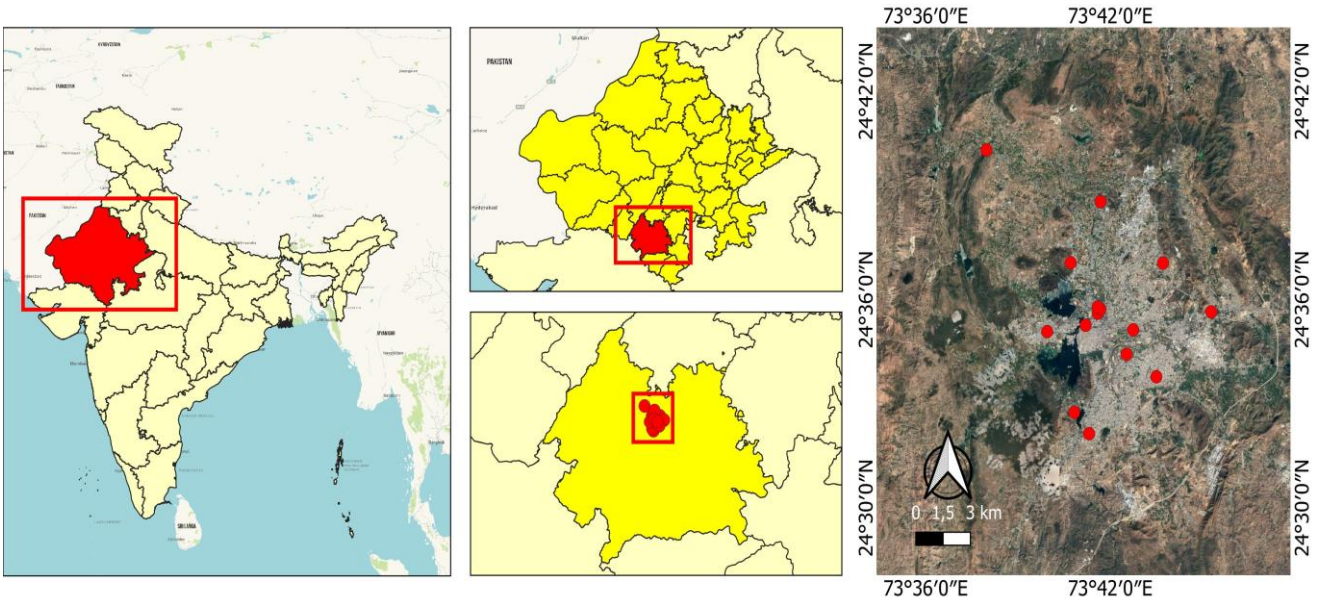

Figure 1. Location map of plant collection zones for the preparation of eco-friendly *Rakhi*

Table 1. Details of the participants in the eco-friendly *Rakhi*-making competition

Name of the student	Class	Area of plant collection	Age (years)	Code no.
D. Sharma	M.Sc. Botany IV Semester	Kankroli, Rajsamand	23	1
R. Gupta	M.Sc. Botany IV Semester	Madhuban, Udaipur	23	2
Y. Yadav	M.Sc. Botany IV Semester	Bicchiwada, Dungarpur	24	3
P. Dhakad	M.Sc. Botany IV Semester	Madhuban, Udaipur	24	4
M. Banu	M.Sc. Botany IV Semester	Nathdwara, Rajsamand	23	5
T. K.Chundawat	B.Sc. III Year	Chitrakoot Nagar, Udaipur	20	6
R. K. Chundawat	B.Sc. III Year	Chitrakoot Nagar, Udaipur	20	7
M. Khan	B.Sc. II Semester	Sajjan Nagar, Udaipur	18	8
R. Meghwal	B.Sc. II Semester	Bedla, Udaipur	18	9
K. Ganchha	B.Sc. II Semester	Madhuban, Udaipur	18	10
H. Sanadhya	B.Sc. II Semester	Shreenathji temple, Hathipole, Udaipur	17	11
C. Maurya	B.Sc. II Semester	Near RTO, Pratapnagar, Udaipur	18	12
A. Siddiq	B.Sc. II Semester	Mullatalai, Udaipur	18	13
G. Lohar	M.Sc. Botany II Semester	Shiv Nagar, Sec. 14, Udaipur	21	14
N. Kumawat	M.Sc. Botany II Semester	Neemach Kheda, Udaipur	20	15
J. Kumari	M.Sc. Botany II Semester	Madhuban, Udaipur	22	16
K. Choudhary	M.Sc. Botany II Semester	College campus, Udaipur	21	17
G. Vaishnav	M.Sc. Botany II Semester	Dangiyon ki Hundar, Madar, Udaipur	21	18
S. Jat	M.Sc. Botany II Semester	Residency Road, Udaipur	21	19
P. K. Daroga	M.Sc. Botany II Semester	Mali colony, Udaipur	22	20
L. Chawla	B.Sc. III Year	Mulla Talai, Gandhi Nagar, Udaipur	20	21
M. Menaria	M.Sc. Botany II Semester	Gayatri Nagar, Sec. 5, Udaipur	23	22
P. Suthar	B.Sc. III Year	Chitrakoot Nagar, Udaipur	20	23

Figure 2. Various eco-friendly *Rakhi* was displayed in the competition held at the Government Meera Girls College, Udaipur, India. A. Code No. 01, B. Code No. 02, C. Code No. 05, D. Code No. 09, E. Code No. 11, F. Code No. 12, G. Code No. 15, H. Code No. 16, I. Code No. 17, J. Code No. 18, K. Code No. 21, L. Code No. 20, M. Code No. 22, N. Code No. 23

Data analysis

After observing the eco-friendly *Rakhi* prepared by the participants carefully for obtaining the details of plant species utilized, the plants were identified using Flora of Rajasthan (Shetty and Singh 1987-1993), and a recent updated botanical nomenclature was adopted for all the plant species (POWO 2025). For the correct identification of some of the plant species, pictures of those plants were also procured from their original collection sites.

Descriptive statistics were used to analyze the life form, plant part used, dominant botanical families, wild/cultivated status, source of collection of the plant material, and exotic plant numbers. The obtained data were pursued for further analysis using a quantitative ethnobotanical index known as Relative Frequency of Citation (RFC). It is calculated by dividing the number of informants who used a particular species by the total number of informants who participated in the study. Usually, it ranges from zero to one. Near-zero values suggest that only a few persons use the particular species, and higher values indicate that more persons are using that particular species for the same purpose (Tardío and Pardo-de Santayana 2008).

All the plants are enumerated alphabetically with their botanical name and family, common and local name, habit, part used, code number, and relative frequency of citation in Table 2. The database available on Plants of the World Online (POWO 2025) was checked to find out the nativity of each plant species, and details of exotic plant species are given in Table 3. To know the conservation status of each plant, the IUCN Red List was thoroughly checked (IUCN 2025), and the findings are discussed in the next section. Besides, an attempt was made to analyze the results of the study in context with UN Sustainable Development Goals (United Nations 2025) and National Education Policy-2020 (Ministry of Human Resource Development Government of India 2025).

RESULTS AND DISCUSSION

Details of participants in the *Rakhi* competition

All the participants were females of young age (Mean age = 20.65 years). Ten girls were studying in an Undergraduate course (Four in the Final year and six in the Second semester of a three-year degree course). The remaining 13 girls were enrolled in a Postgraduate course (a two-year degree course), i.e., Master's in Botany (Five in Fourth semester and Eight in Second semester), offered by the college. Two girls prepared eco-friendly *Rakhi* at Rajsamand and one at Dungarpur district; both districts have adjoining boundaries with Udaipur District. The remaining 20 girls prepared *Rakhi* at their homes situated in various localities of Udaipur city and brought them to the college for participation in the competition (Table 1). About 80% girls revealed that the reason behind choosing a particular plant was primarily easy availability in their homes. The rest of the girls were told that there was no specific reason behind the selection of a particular plant for the preparation of *Rakhi*.

This competition was organized for the first time in Rajasthan, India, and no such event has been organized in Udaipur till now. The gender bias in this study is due to the belonging of all the participants to an exclusively girls' college. This may have influenced the material preference, aesthetic choice, and crafting techniques, as cultural expectations are usually associated with females who have prior experience with craft-based activities. If the study had included male participants, the plant selection would have been different. Moreover, all the participants were studying Botanical sciences; thus, having better knowledge of plants and overall biodiversity, as well as more awareness about ecology. This scientific background could lead to an academic bias in plant selection instead of community-based ethnobotanical practices. On the other hand, unequal access to plant materials depending on the location (urban/rural) and the socio-economic status of participants could also skew the results. Use of more visually attractive plant material, irrespective of their ecological or traditional relevance, could have affected the study results. These biases reflect the significance of diverse participants' inclusion, collaboration across disciplines, and the correct interpretation of ethnobotanical information in context. Therefore, the present findings could be expanded and further validated with larger research incorporating wider demographics in future such events.

Cataloguing of plants used for the preparation of *Rakhi*

The ethnobotanical investigation revealed that students utilized 53 plant species (51 genera) belonging to 28 families for the preparation of eco-friendly *Rakhi* (Table 2). Two genera, namely, *Jasminum* and *Vigna,* among 51, contributed the maximum species (2 each). Among the 53, 44 plants (23 families) were Dicotyledons, and 8 plants (4 families) were Monocotyledons of Angiosperms. The dominance of Dicot plants (23 families) was also observed in another ethnobotanical study by Mohanty et al. (2025), where 47 plants were documented for use in various rituals practiced among people of Jajpur district, Odisha, India. This distribution aligns with global plant diversity patterns, where dicots are more commonly used in traditional and cultural practices due to their diverse leaf and flower forms. One plant, *Platycladus orientalis*, whose leaves were utilized to decorate the *Rakhi*, was a Gymnosperm demonstrating that non-flowering plants could not be excluded entirely if aesthetically observed as useful. The analysis of plant families revealed that the dominant families were Fabaceae (8 plants), followed by Apocynaceae and Poaceae, each with 5 plants, Asteraceae and Euphorbiaceae, each with 4 plants, Malvaceae (3 plants), and Cucurbitaceae and Oleaceae, each with 2 plants. The rest of the 20 families were represented by only one plant species (Figure 3).

Table 2. Plants are utilized for making eco-friendly *Rakhi* in the competition

Botanical name & family	Common and local name	Habit	Part used	Source	Plant collection site	Code no.	RFC
Abelmoschus esculentus (L.) Moench (Malvaceae)	Okra, Bhindi	Herb	Fruit	Cultivated, Non-native	Market	09	0.04
Bergera koenigii L. (Rutaceae)	Curry Leaf, Kadhi Patta	Tree	Dried leaves	Cultivated, Native	Home Garden	13	0.04
Bougainvillea spectabilis Willd. (Nyctaginaceae)	Great Bougainvillea	Shrubby vine	Flower	Cultivated, Non-native	College Campus Garden	19	0.04
Brassica juncea (L.) Czern. (Brassicaceae)	Indian Mustard, Rai	Herb	Seed	Cultivated, Non-native	Market	22	0.04
Butea monosperma Kuntze (Fabaceae)	Bastard Teak, Khakara	Tree	Leaves	Wild, Native	Roadside	11	0.04
Cajanus cajan (L.) Huth (Fabaceae)	Pigeon Pea, Arhar	Herb	Split seed	Cultivated, Native	Market	09, 21	0.09
Calotropis procera (Aiton) W.T.Aiton (Apocynaceae)	Apple Of Sodom, Aak	Shrub	Flower	Wild, Native	Roadside	20	0.04
Camellia sinensis (L.) Kuntze (Theaceae)	Tea, Chai	Shrub	Dried leaf powder	Cultivated, Native	Market	02	0.04
Cascabela thevetia (L.) Lippold (Apocynaceae)	Yellow Oleander, Peeli Kaner	Tree	Floral part	Cultivated, Non-native	College Campus Garden	02, 04, 14	0.13
Catharanthus roseus (L.) G.Don (Apocynaceae)	Madagascar Periwinkle, Sadabahar	Herb	Leaves, Flower	Cultivated, Non-native	College Campus Garden	18, 20	0.09
Cicer arietinum L. (Fabaceae)	Gram, Chana	Herb	Split seed	Cultivated, Non-native	Market	02, 04, 09, 19, 20	0.21
Combretum indicum (L.) DeFilipps (Combretaceae)	Rangoon Creeper, Madhumalti	Climber	Flower	Cultivated, Non-native	College Campus Garden	10	0.04
Cosmos sulphureus Cav. (Asteraceae)	Orange Cosmos	Herb	Flower	Cultivated, Non-native	College Campus Garden	07, 16	0.09
Cynodon dactylon (L.) Pers. (Poaceae)	Bermuda Grass	Herb	Leaf	Wild, Non-native	Roadside	07, 15	0.09
Echinochloa colonum (L.) Link (Poaceae)	Indian Barnyard Millet, Sama	Herb	Seed	Cultivated, Native	Market	02	0.04
Elettaria cardamomum (L.) Maton (Zingiberaceae)	Cardamom, Ilayachi	Herb	Outer shell of fruit, complete fruit	Cultivated, Native	Market	01, 05	0.09
Euphorbia thymifolia L. (Euphorbiaceae)	Gulf Sandmat, Chhota Dudhi	Herb	Leaves	Wild, Non-native	Roadside	23	0.04
Glycine max (L.) Merr. (Fabaceae)	Soyabean	Herb	Seed	Cultivated, Non-native	Market	12	0.04
Gossypium spp. (Malvaceae)	Cotton, Rui	Tree	Seed-hair fibre	Cultivated, Native	Market	11, 18, 21, 23	0.17
Illicium verum Hook.fil. (Schisandraceae)	Star Anise, Chakari Phul	Tree	Dried fruit	Cultivated, Non-native	Market	05	0.04
Ipomoea quamoclit L. (Convolvulaceae)	Cypress Vine	Climber	Flower	Cultivated, Non-native	Roadside	10	0.04
Ixora coccinea L. (Rubiaceae)	Jungle Geranium	Shrub	Flower	Cultivated, Native	College Campus Garden	17	0.04
Jasminum officinale L. (Oleaceae)	Common Jasmine, Chameli	Shrub	Flower bud	Cultivated, Native	College Campus Garden	08, 10, 16, 17	0.17
Jasminum sambac (L.) Aiton (Oleaceae)	Jasmine, Mogra	Shrub	Flower bud	Cultivated, Native	College Campus Garden	08, 11, 14	0.13
Jatropha integerrima Jacq. (Euphorbiaceae)	Peregrina	Shrub	Flower	Cultivated, Non-native	Home Garden	15, 22	0.09
Lantana camara L. (Verbenaceae)	Lantana	Shrub	Flower	Wild, Non-native	Roadside	16, 17	0.09
Mallotus philippensis (Lam.) Müll.Arg. (Euphorbiaceae)	Kamala Tree, Kumkum	Tree	Fruit powder	Wild, Native	Home Garden	18	0.04
Malvastrum coromandelianum (L.) Garcke (Malvaceae)	False Mallow, Kharenti	Herb	Leaves	Wild, Non-native	Roadside	03, 18	0.09
Manihot esculenta Crantz (Euphorbiaceae)	Tapioca Sago, Sabudana	Herb	Seed	Cultivated, Non-native	Home Garden	15	0.04
Momordica dioica Roxb. ex Willd. (Cucurbitaceae)	Spiny Gourd, Kikoda	Climber	Fruit	Wild, Native	Roadside	09	0.04

Musa × *paradisiaca* L. (Musaceae)	Banana, Kela	Herb	Leaves	Cultivated, Non-native	Home Garden	11	0.04
Nerium oleander L. (Apocynaceae)	Oleander, Kaner	Tree	Flower	Cultivated, Non-native	Home Garden	08	0.04
Oryza sativa L. (Poaceae)	Rice, Chawal	Herb	Seed	Cultivated, Non-native	Market	03, 05, 06, 07, 18, 19, 20	0.30
Parthenium hysterophorus L. (Asteraceae)	Congress Grass, Gajar Ghas	Herb	Flower	Wild, Non-native	Roadside	17	0.04
Phaseolus vulgaris L. (Fabaceae)	Kidney Bean, Rajma	Herb	Seed	Cultivated, Non-native	Market	12	0.04
Phoenix dactylifera L. (Arecaceae)	Date Palm, Khajur	Tree	Leaf	Wild, Non-native	Roadside	06, 07, 23	0.13
Phyllanthus emblica L. (Phyllanthaceae)	Indian Gooseberry, Amla	Tree	Leaves	Cultivated, Native	Home Garden	18	0.04
Piper nigrum L. (Piperaceae)	Black Pepper, Kali Mirch	Climber	Dried fruit	Cultivated, Native	Market	06, 12, 13, 15, 20, 23	0.26
Pistacia vera L. (Anacardiaceae)	Pistachio, Pista	Tree	Outer shell	Cultivated, Non-native	Market	04, 06, 13, 21, 23	0.21
Platycladus orientalis (L.) Franco (Cupressaceae)	Oriental Thuja, Morpankhi	Tree	Leaves	Cultivated, Non-native	College Campus Garden	10, 22	0.09
Plumeria alba L. (Apocynaceae)	White Frangipani, Champa	Tree	Flower	Cultivated, Non-native	College Campus Garden	20	0.04
Portulaca grandiflora Hook. (Portulacaceae)	Rose Moss	Herb	Flower	Cultivated, Non-native	College Campus Garden	14	0.04
Rosa spp. (Rosaceae)	Rose, Gulab	Shrub	Flower, leaves	Cultivated, Native	Home Garden	08, 10, 11, 14, 17, 19, 20	0.30
Syzygium aromaticum (L.) Merr. & L.M.Perry (Myrtaceae)	Clove, Laung	Tree	Dried flower buds	Cultivated, Non-native	Market	01, 05, 06, 07, 20	0.21
Tagetes erecta L. (Asteraceae)	Mexican Marigold	Herb	Flower	Cultivated, Non-native	Home Garden	11	0.04
Tinospora cordifolia (Willd.) Hook.fil. & Thomson (Menispermaceae)	Heart-Leaved Moonseed, Giloy	Climber	Root	Wild, Native	Roadside	04	0.04
Trichosanthes cucumerina L. (Cucurbitaceae)	Snake Gourd, Chichinda	Climber	Stem	Wild, Native	Roadside	02	0.04
Tridax procumbens L. (Asteraceae)	Coatbuttons	Herb	Flower	Wild, Non-native	Roadside	14	0.04
Triticum aestivum L. (Poaceae)	Wheat, Gainhu	Herb	Flour, Seed	Cultivated, Native	Market	15, 21	0.09
Vicia lens (L.) Coss. & Germ. Syn. *Lens culinaris* Medik. (Fabaceae)	Lentil, Masur	Herb	Split seed	Cultivated, Non-native	Market	05, 09, 12, 19	0.17
Vigna mungo (L.) Hepper (Fabaceae)	Black Gram, Urd Bean	Herb	Split seed, whole seed	Cultivated, Native	Market	02, 04, 07, 20, 21	0.21
Vigna radiata (L.) R.Wilczek (Fabaceae)	Green Gram, Mung Bean	Herb	Split seed, whole seed	Cultivated, Native	Market	02, 03, 04, 07, 12, 15, 20, 21	0.35
Zea mays L. (Poaceae)	Maize, Makai	Herb	Spathe, seed	Cultivated, Non-native	Market	05, 06	0.09

Note: RCF: Relative Frequency of Citation

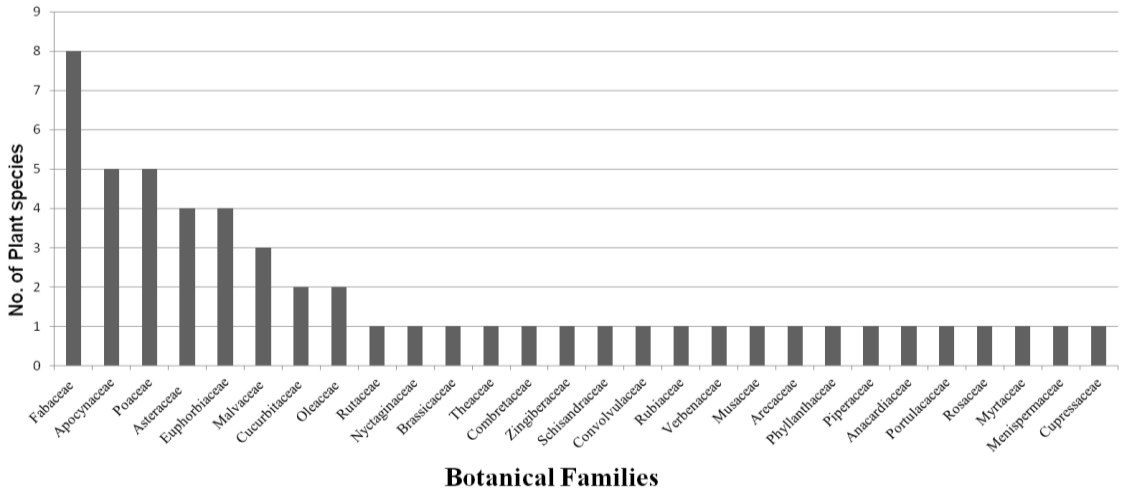

Figure 3. Distribution of 53 plants used for *Rakhi* preparation in botanical families

As most of the pulses belonging to the family Fabaceae are easily available in Indian kitchens, it might be the reason behind its dominance in the study where students utilized plants available in their vicinity for preparing *Rakhi*. Fabaceae was also the most widely used botanical family among 25 plants used for the treatment of various ailments by the Damor tribe in Simalwara, Dungarpur, Rajasthan (Shrimali et al. 2021). Plants of the second dominant family, Apocynaceae, were common ornamentals having fragrant flowers, and Poaceae family grains were preferred for easy availability and symbolic purposes, such as Wheat and Rice. However, the dominance of a few botanical families in the study possibly indicates limited knowledge of lesser-known useful species available in their surroundings, or cultural preference and ecological abundance of certain plant species.

Ethnobotanical sciences contribute not only to agricultural innovation, building plant-based products, or to the health industry, but also have a deeper understanding of ecological knowledge, which helps in better management of landscapes and resources. Traditional Ecological Knowledge (TEK) can play a crucial role in contemporary biodiversity conservation and sustainable development. In fact, the biocultural approach that integrates cultural values and local knowledge in the sustainable use of plant diversity could be useful for future conservation and developmental policymaking (Pei 2013). In view of this, the eco-friendly *Rakhi*-making initiative in Udaipur serves as an innovative ethnobotanical intervention through the utilization of over 50 plant species in *Rakhi*-making, uncovering the layers of TEK embedded in material selection, symbolism, and cultural storytelling. Recently, Marín et al. (2024) reported 65 taxa that were utilized to make sculptures and other architectural grains in annual Agricultural fairs at Baix Llobregat (Catalonia, NE Iberian Peninsula). Chiocchio et al. (2024) carried out an extensive ethnobotanical study in the Bologna district in Northern Italy. They documented the use of 32 plant taxa for various craft work as reported by 1172 informants. The present study explores similar dimensions of plants that were used for artistic purposes for the celebration of the *Rakhi* festival in a sustainable way. In fact, such events help activate local knowledge systems and adapt them to modern environmental concerns. Additionally, this initiative has built a living archive of ethnobotanical knowledge that might otherwise be lost due to globalization and synthetic consumer products. By combining traditional plant use with modern educational efforts, it shows how ethnobotanical knowledge can be actively preserved and reinterpreted.

Besides, from an environmental perspective, this initiative recasts the material economy of goods available for festivals. It substitutes locally-sourced, biodegradable, and renewable materials for synthetic threads, plastics, glitters, and foils. This shift encourages a circular economy based on natural cycles and low-carbon alternatives. In terms of education, it helps the participants, especially young people, to develop a value-based sustainability perspective by exposing them to the connections between ethics, the environment, and culture. It transforms *Rakhi*-making from a mere craft into a pedagogical tool for sustainability education, as well as promoting mindfulness in material use and cultural practice.

Growth habit and plant part used

The life form of these plants exhibited that 47% are Herbs (n=25), 25% are Trees (n=13), 15% are shrubs (n=8), and 13% (n=7) were climbers (Figure 4). Use of climbers was done for making a tying thread for *Rakhi*, whereas herbs were used for their easy access, soft texture, and flexible properties. The floral parts of these 53 plants were among the most used parts, followed by seeds, leaves, fruits, roots, and stems. An ethnobotanical study carried out by Lata et al. (2024) also reported maximum use of the floral part, followed by leaves, seeds, and twigs of 47 plants used for the celebration of the festival of flowers in Himachal Pradesh, India. Color, fragrance, and symbolic value could be the main reasons behind the maximum use of the floral parts of the plant species reported in the present study. Each plant part has different implications for sustainability and cultural acceptability, which is useful to assess the ecological impact of such eco-friendly

initiatives. Harvesting of flowers from seasonal blooms or cultivated species for rituals or decoration is often regulated by some customary practices that avoid overharvesting. However, continuous flower collection from wild populations in ecologically sensitive areas may disrupt the reproductive cycle of the plant and overall jeopardize its survival. Leaves and seeds, on the other hand, are relatively renewable resources, and their collection would have a low ecological impact. For example, the use of seeds from cultivated crops having high RFC values (*Oryza sativa* and *Vigna radiata*) poses minimal sustainability concerns. Moreover, the limited use of destructive parts (stem and roots) for *Rakhi*-making in the present study could be an important approach to achieve sustainability and signifies the deeper ecological understanding of participants.

Notably, two plant parts of the same plant were also used for making *Rakhi*, for example, *Catharanthus roseus, Rosa* spp., and *Zea mays* (Table 2). Incorporating multiple plant parts from the same species reflects a deeper understanding of plant morphology and possibly more culturally acceptance of the plant species. This also exhibits a rather multi-functional approach used by students, possibly to reduce waste or to enhance visual perception. Overall, the predominance of herbs and floral parts in *Rakhi*-making underscores a preference for materials that are aesthetically appealing, easy to handle, and culturally significant.

Native v/s exotic plants used for the preparation of *Rakhi*

Exotic species are those that move outside their native distributional range due to accidental or anthropogenic reasons and usually considered to have negative ecological impact. However, it is not always necessary. Exotic species may flourish in their non-native sites either due to deliberate cultivation by man or due to their excessive invasiveness. Impact of exotic flora on traditional knowledge is usually considered to be negative, but studies have shown the adaptive nature of indigenous knowledge systems (Gama et al. 2018). For example, exotic species have entered into indigenous pharmacopeia of Shurugwi in South-central Zimbabwe (Maroyi 2018). Jain and Jain (2020) reported the use of exotic plant species for worship/temple decoration purposes from Udaipur, India. This indicates the adaption of exotic plants by local communities. In this regard, the present study revealed that out of 53 species, 60% of the plants used by participants to prepare eco-friendly *Rakhi* were not native to India. These plant species were introduced to India from other countries such as North and South America, Africa, China, Middle East and South East Asia (Table 3). *Rosa* spp. is also included in the list of exotic plants, which makes the total count 32. Besides the exotic crop plants and vegetables, *Brassica juncea, Abelmoschus esculentus, Cicer arietinum, Glycine max, O. sativa, Phaseolus vulgaris, Vicia lens,* and *Z. mays,* as well as spices and nuts, such as *Illicium verum, Pistacia vera,* and *Syzygium aromaticum*, all other exotic species were well known for their beautiful appearance as flowers and mostly grown for ornamental purposes along with other native plants of India. This exhibits the intermingling of native and non-native flora, creating an opportunity to integrate with knowledge of local communities, which was reflected in using these plants for making *Rakhi*. Patil (2024) documented the use of 51 alien Angiosperm plant species for the worship of goddess Durga during the traditional Durga Puja festival in various Indian states. Notably, among them, nine exotic plants, namely, *Cascabela thevetia, Cynodon dactylon, Combretum indicum, Hibiscus rosa-sinensis, Jasminum sambac, Nerium indicum, Tabernaemontana divaricata, Tagetes erecta* and *Triticum aestivum* used for worship purpose (Patil 2024) are also common in the present study revealing their cultural and religious significance and acceptance in India. Similarly, five exotic plants out of 47, namely, *C. thevetia, H. rosa-sinensis, Lantana camara, N. indicum* and *P. alba* used by Soliga tribes for socio-cultural purposes in Anthiyur Taluk, Erode District, Tamil Nadu, India (Menaka et al. 2025) are also observed in the current study for making eco-friendly *Rakhi*.

The cultural intricacy of the floral diversity has been explored earlier in South Rajasthan by several scientists. For example, floral *Rakhi* from flowers of *L. camara* and *Leucas aspera* are prepared by tribal girls to celebrate the *Rakhi* festival (Jain and Sharma 2015). A study at Maputaland-Pondoland-Albany biodiversity hotspot, South Africa reported varying degree of cultural assimilation for 17 invasive shrub and tree species highlighting their amalgamation among daily lives of local people (Wootton and Shackleton 2023). Notably, in the present study, the use of flowers of invasive plant species, namely, *Parthenium hysterophorus* and *L. camara,* was also observed for making *Rakhi*. It shows that the abundance of these invasive species among native flora is making their cultural integration more accessible in the community. Although *L. camara* and *P. hysterophorus* are non-native to India and considered invasive due to their detrimental ecological impact but they now grow widely in the wild. Their use for cultural purpose indicates that the cultural distinction between native/wild/invasive is now being blurred. Further, this cultural assimilation of invasive flora in traditional crafts reveals how human creativity and cultural practices evolve in changing ecological landscapes.

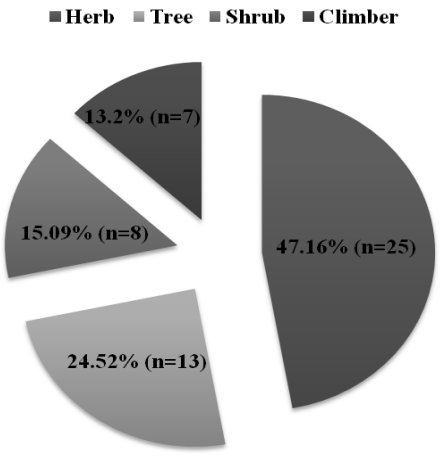

Figure 4. Percentage of growth forms of plants used for the eco-friendly *Rakhi* competition

Table 3. Exotic plant species used for making eco-friendly *Rakhi*

Name of plant	Nativity
Abelmoschus esculentus (L.) Moench	Tropical Africa
Bougainvillea spectabilis Willd.	Brazil
Brassica juncea (L.) Czern.	Tibet
Cascabela thevetia (L.) Lippold	Tropical America and the West Indies
Catharanthus roseus (L.) G.Don	West Indies and Madagascar
Cicer arietinum L.	Iran, Iraq, Türkey
Combretum indicum (L.) DeFilipps	Burma, Malaya, New Guinea
Cosmos sulphureus Cav.	Mexico to Central America
Euphorbia thymifolia L.	Tropical America
Glycine max (L.) Merr.	Eastern Asia
Illicium verum Hook.fil.	China Southeast
Ipomoea quamoclit L.	Tropical America
Jatropha integerrima Jacq.	Cuba
Lantana camara L.	Tropical America
Malvastrum coromandelianum (L.) Garcke	South America
Manihot esculenta Crantz	Tropical America
Musa × *paradisiaca* L.	Malaya, Philippines
Nerium indicum Mill.	China
Oryza sativa L.	China
Parthenium hysterophorus L.	West Indies, Central and North America
Phaseolus vulgaris L.	South America, Mexico
Phoenix dactylifera L.	Gulf States, Iran, Iraq, Oman
Pistacia vera L.	Afghanistan, Iran, Kazakhstan
Platycladus orientalis (L.) Franco	China and Japan
Plumeria alba L.	West Indies
Portulaca grandiflora Hook.	South America
Syzygium aromaticum (L.) Merr. & L.M.Perry	Maluku
Tagetes erecta L.	Africa/Mexico
Tridax procumbens L.	South America
Vicia lens (L.) Coss. & Germ.	Western temperate Asia
Zea mays L.	Central America

Biodiversity patterns

Another important observation was the use of roots of *Tinospora cordifolia*, twigs of *Euphorbia thymifolia,* and leaves of *Malvastrum coromandelianum* and *Butea monosperma* for making eco-friendly *Rakhi*. This indicates a wonderful exposition of human creativity using wild plants growing in their vicinity, highlighting the resourcefulness and ecological awareness of participants. The *Rakhi* made by code No. 09 utilized a combination of vegetables and pulses (two each). She used fruit slices of *Momordica dioica* and *A. esculentus*, which were really unique among the participants, and all the visitors were amused to see her imagination of making a *Rakhi* from these fruits and appreciated her innovative thinking beyond the conventional floral *Rakhi* models. The participant exhibited an exceptional ability to reimagine everyday plants in a fresh aesthetic and symbolic context, which is key to ethnobotanical creativity. It is important to mention here that *M. dioica* is a valuable Non-Timber Forest Product in Udaipur, which is usually sold at INR 250-300/kg during the rainy season. The use of leaves from the sacred plant, *Phyllanthus emblica*, as well as the leaf powder of *Camellia sinensis* for making *Rakhi* was another unique contribution by code No. 02 and 18, respectively. Overall, this reflects the flexibility of cultural practices integrating new and local plant resources, as well as promoting the biological awareness of invasive, wild, and edible plants. In this context, the eco-friendly *Rakhi* has become not only a craft but also a symbol of adaptive cultural resilience and sustainable innovation among youth.

Analysis of RFC values

RFC is a crucial quantitative tool to strengthen statistical integrity in ethnobotanical studies. It helps to find out the importance of a plant species as reported by informants in a study area. It measures the cultural significance of a species, that how widely known/valuable a plant is in a community, and higher RFC values suggest strong cultural relevance. The RFC values observed in this study ranged from 0.04 to 0.35, which were grouped as Low (0.01-0.10), Moderate (0.11-0.20), and High (0.21-0.40). Figure 5 depicts that the maximum plants had low RFC values (n=39), 6 plants had moderate, and 8 plants had high RFC values. The highest RFC value (0.35) was of *V. radiata* (n=8), followed by *O. sativa* and *Rosa* spp. (RFC=0.30 each), which 7 participants used, and *Piper nigrum* (RFC=0.26), which 6 participants used to make *Rakhi* (Table 2).

The reason behind the higher RFC value of Pulse crops, such as Mung Bean (*V. radiata*), Urd Bean (*Vigna mungo*), Gram (*C. arietinum*) and Lentil (*V. lens*); Cereals such as Rice (*O. sativa*); Spices such as Black Pepper (*P. nigrum*), Green Cardamom (*Elettaria cardamomum*) and Clove (*S. aromaticum*), and Dry fruits such as Pistachio (*P. vera*), could be due to their easy availability and access at the

participant's own homes. Rice was also reported to have the highest cultural significance index among 51 ritual plants used by the Aceh Tribe in Peureulak Sub-district, East Aceh, Indonesia, indicating its high importance and irreplaceable attribute for performing rituals (Sutrisno et al. 2020). Besides, the high RFC values of Rose (*Rosa* spp.) and Jasmine (*Jasminum* spp.) show their wide acceptance as beautiful fragrant flowers, as well as easy availability of these plants in surrounding areas, because, as ornamental plant species, these plants are frequently grown in most gardens and parks. Jasmine and Rose were also found to be the most favored plants for wearing in hair by young students and faculty members of a Women's College in Tamil Nadu, India (Ganga et al. 2025). However, higher RFC values also highlight the key species having cultural dependency and the need arising for their sustainable harvesting or initiating conservation programs (Chinnasamy et al. 2025; Krstin et al. 2024). An ethnobotanical plant inventory utilized by mountainous rural people of North West Portugal revealed that out of 98, 12 plants were used for performing various rituals, and the plant *Ruta graveolens* had the highest RFC value (Sá et al. 2024).

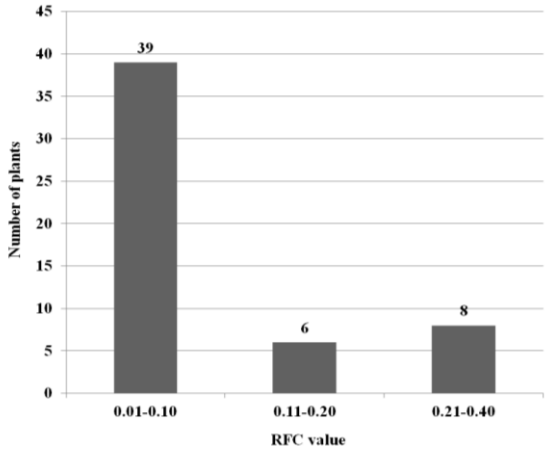

Figure 5. Number of plants grouped in three categories of RFC values

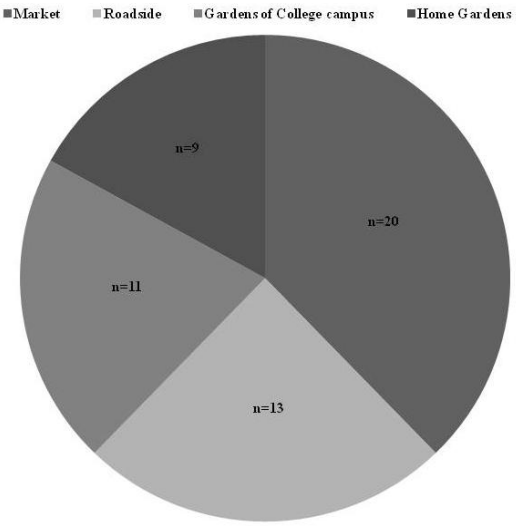

Figure 6. Percentage of plants procured from different areas (n = number of plants)

Cultural innovation and youth engagement

This ethnobotanical study is a first of its kind, and the creativity reflected in this competition revealed that there is enormous potential in the human mind, which can use its surrounding resources to fulfill all its needs. As living in urban spaces limits access to wild species, people start adapting to whatever is easily available to them. Moreover, habitat loss and overharvesting also jeopardize the accessibility of wild plant species. Steadily, a new foundation is laid between plants and man to build up a resilient need-based relationship. To illustrate, participants used 40 cultivated plants as these were frequently available in their surrounding areas, and only 13 wild plants to make *Rakhi* (Table 2). It is important to mention here that out of 13 wild plants, 7 species namely, *C. dactylon, E. thymifolia, L. camara, M. coromandelianum, P. hysterophorus, P. dactylifera* and *T. procumbens* were non-native to India but due to their rapid naturalization in the country, they are now growing in wild. Interestingly, integration of 40 cultivated plants into cultural rituals reflects their widespread acceptance among local traditions and belief systems.

Moreover, in present study, another important observation was that 38% plants were procured from markets, 24% from roadsides, 21% from gardens of the college campus and 17% from home gardens (Figure 6). The plants collected from markets include mostly lentils, vegetables, spices, and nuts. In contrast, most of the ornamental and fragrant plants were collected from gardens located at the college and at the homes of participants. This further indicates more use of plants growing in urban settings, as 38% of the plants were collected from gardens and markets, whereas collection of only 13 plants were done from roadside areas. Only 6 participants utilized the plants growing on the College campus and the nearby area in Madhuban (Table 1). This reflects the students' knowledge, perception, and attitudes toward plant biodiversity on campus and highlights the importance of botanical richness in educational settings for promoting sustainability and ecological consciousness. This also exhibits the adaptability of the human brain to satisfy the demands in every situation. However, a recent study on floral diversity and its role in environmental awareness conducted through an online questionnaire among faculty members and students of V.V.Vanniaperumal College for Women, Virudhunagar, Tamil Nadu has shown a lack of awareness about the ecological, medicinal, and environmental role of flowers and recommends integrating floral knowledge into education to strengthen ecological literacy (Ganga et al. 2025).

A recent global bibliometric analysis by Marsandi et al. (2025) has revealed that education systems can play a vital role in preserving cultural heritage by training the young generation to respect and uphold traditional values. Furthermore, integrating local wisdom into curricula enables students to create community-based solutions for local issues. It requires an interdisciplinary approach that emphasizes ecological, educational, and socio-economic factors, aligning scientific learning with cultural values, environmental consciousness, and community well-being.

Therefore, there is a need to conduct more such eco-consciousness-promoting events incorporating traditional wisdom along with a sustainability outlook among the young generation. This will raise environmental awareness but will showcase various levels of human creativity using different plants in their surroundings. These programs could not only foster appreciation for biodiversity but could also connect cultural heritage with modern ecological responsibility. For example, these initiatives could be useful for fulfillment of UN Sustainable Development Goals (SDGs) such as SDG 4 - providing quality education by engaging students in real world sustainability practices; SDG-12 by encouraging eco-friendly, biodegradable material for making *Rakhi* to become responsible consumer and producer and SDG-15 by raising awareness about plant diversity and their conservation needs, thereby, helping in protection of life on land. Besides, it also aligns with the National Education Policy 2020, which emphasizes holistic, multidisciplinary education imparting skill-based learning and availing local knowledge systems. This art-integrated competition is helpful for experiential learning by blending Ethnobotany, Environmental Sciences, and traditional art, as well as promoting ethical engagement with natural resources through value-based education. The plant-based innovations offer pathways for addressing global challenges and foster economic resilience, environmental preservation, and social equity (Krzywonos and Piwowar-Sulej 2022). Therefore, encouraging similar initiatives across institutions can deepen students' understanding of the interconnection between culture, environment, and responsible citizenship.

In the current era, urbanization is rapidly increasing and bringing changes to traditional lifestyles and the use patterns of urban plant diversity. Though it has been shown to affect the traditional medicinal knowledge and biodiversity, it also provides opportunities for innovation and cultural extension (Arjona-García et al. 2021). Interestingly, the use of plants growing in urban settings, for example, *Bougainvillea spectabilis*, *C. indicum, Cosmos sulphureus, Ixora coccinea, P. orientalis, T. erecta,* etc., was also observed in the present study, reflecting the importance of urban biodiversity not only for aesthetic purposes but also for cultural utility. This also provides rich insights into how plants are intricately connected with people, whether growing in rural or urban settings, highlighting the dynamic relationship between people and plants in everyday life. *Tagetes erecta* has also shown a high cultural importance index as being used for various rituals and socio-religious activities among 95 local vegetables sold at a community market in Kantarawichai District, Thailand (Saensouk et al. 2025).

The urban green spaces act as living repositories of plant-based materials that are easily accessible, visually attractive, and seasonally synchronized with the *Rakhi* festival, encouraging their use in traditional crafts. On the other hand, home gardens in urban areas are another valuable land area filled with urban plant diversity vis-à-vis traditional knowledge and cultural values. In the present study, nine plants were collected from home gardens and 11 from College campus gardens (Figure 6). As cities are growing rapidly, recognizing this role of urban flora can enhance both community engagement and sustainability education, as urban biodiversity can contribute to cultural resilience and creativity. The urban ecological habitats lie at the intersection of biodiversity, cultural heritage, and sustainability, and therefore, are carefully negotiated. Further, these findings emphasize the need for expansion of the conventional Ethnobotany regime towards Urban Ethnobotany, which is the need of the hour (de Santana et al. 2024; Hou et al. 2024).

Conservation implications

Ethnobotanical studies also indicate the gap between traditional knowledge and formal conservation science. These studies help to identify the plant species that are culturally valuable but are vulnerable and need conservation prioritization (Pei et al. 2020). In the present study, it was observed that, as per the IUCN Red List, *P. orientalis* and *P. vera* belong to the Near Threatened category (IUCN 2025), indicating that if the current trends continue for their exploitation, they are at great risk of becoming endangered in the near future. Besides, a decreasing population trend is mentioned for *P. emblica* (IUCN 2025), whose fruits are well-known for their nutraceutical properties and cultivated widely in South Rajasthan (Avinash et al. 2024). This raises concerns about the sustainable use of plant species and the need to promote conservation strategies to prevent extinction. Additionally, implementing sustainable harvesting guidelines based on ecological assessments is essential. These guidelines should specify acceptable extraction limits, ensure natural regeneration, and support habitat conservation. Rotation harvesting and controlled collection periods are vital to reduce pressure on wild populations. Habitat restoration is also a crucial part of any conservation plan, and traditional knowledge can serve as a valuable guide to saving particular plant species (Haq et al. 2023). Especially, *in-situ* conservation by encouraging the cultivation and use of locally available plant species could be adopted. As the demand for plant-based *Rakhi* increases, community members may be incentivized to grow culturally important species in home gardens or community spaces, thereby restoring degraded flora and supporting local biodiversity. However, there is a risk of overharvesting if the popularity of plant-based *Rakhi* outpaces sustainable supply. Therefore, coupling such initiatives with environmental education on sustainable harvesting and cultivation techniques, responsible use, and conservation planning is crucial. In this way, cultural practices could be used to ensure climate resilience.

Ethnobotany and sustainable bio-economy: A transformative link

Ethnobotany is an emerging and dynamic branch of science that can aid in the development of a sustainable Bioeconomy. In this regard, the recent introduction of the concept, 'One Student, One Product', is a thought-provoking opportunity that merges tradition, sustainability, and entrepreneurship (Saklani 2024). The Ethnobotany-oriented entrepreneurship can not only boost the economic

condition of the local community but can also be helpful to project that particular region on the global tourist canvas. In this context, the recent initiative of biodegradable floral *Rakhi* prepared from dehydrated plant material by CSIR-National Botanical Research Institute, Lucknow, Uttar Pradesh, is worth mentioning. If the participants of the present study can prepare any such eco-friendly *Rakhi* on a large scale and proper marketing of the product is carried out, then this venture could certainly be a valuable source for generating income during the *Rakhi* festival as a micro-seasonal economic benefit. Digital platforms could be used to promote their eco-ethnic *Rakhi*. Financial and logistic assistance or industrial support, thus required for upscaling of such grassroots innovations, could be availed through various schemes of the Government of India and entrepreneurial development programs. Later, hands-on crafting workshops with ethnobotanical relevance could be organized for awareness and skill development among youth. In fact, such competitions, if scaled up, could open doors for farmers and local artisans to supply eco-friendly raw materials to foster a green economy. This insight highlights the applied dimension of Ethnobotany, where traditional plant knowledge meets innovation, especially in the context of environmentally responsible economic models. This aligns with broader goals of sustainable development, cultural preservation, and rural empowerment.

In conclusion, ethnobotanical investigations at festivals of a particular area or a community could provide immense botanical knowledge. That knowledge could be helpful for biodiversity conservation, socio-economic upliftment, ethnic/gastronomic tourism, taxonomic or cultural utility purposes. The use of 53 plants for making eco-friendly *Rakhi* in the present study indicates how the need-based man-plant relationships could be useful to preserve and foster culture-based man-plant relationships, which in turn could strengthen biodiversity conservation by encouraging community engagement in preserving plant diversity. This showcase how cultural traditions can align with environmental education and how a traditional festival, '*Rakhi*', could be celebrated in an eco-friendly manner without compromising the cultural significance. If the innovative *Rakhi* created in this study are scaled with proper training and marketing, they could form the basis of a circular, green business model that not only supports local economies but also positions the region as a hub of eco-cultural innovation. Though the study has its own limitations, it offers a replicable model for using festivals as platforms for raising ecological awareness, reviving local knowledge, and engaging communities in sustainable living practices. However, the urgency and significance of ongoing research cannot be overstated, as it is essential for understanding man-plant relationships and their impact on biodiversity conservation. Besides, a shift towards the use of cultivated and accessible plants is observed in the study, indicating the influence of urbanization, education, and awareness. Based on the results obtained in the study, it is recommended that such kind of investigations should be carried out from time to time to know about both need-based and culture-based man-plant relationships in detail, as well as the impact of surrounding plant diversity in building that relationship.

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Ethnobotany and cultural significance of wild tea plants in Mountain Province, Philippines

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Abstract. *Nasungan LM, Garsi JP, Cue EG. 2025. Ethnobotany and cultural significance of wild tea plants in Mountain Province, Philippines. Asian J Ethnobiol 8: 258-270.* Ethnobotanical studies in the Philippines are crucial for understanding traditional plant uses and developing plant-based products. This study uniquely focuses on assessing the diversity and documenting the ethnobotanical knowledge of wild tea plants in Mountain Province, Philippines, a distinct category of culturally important flora often overlooked in regional research. A Rapid Ethnobotanical Appraisal employed semi-structured interviews with 220 key informants. The Cultural Importance (CI) Index was calculated for each species using frequency counts. The study successfully identified eighteen (18) distinct wild tea plant species, representing 13 taxonomic families. A thorough analysis of their conservation status using the IUCN Red List revealed a diverse profile: twelve (12) species are categorized as Least Concern, three (3) are classified as Vulnerable, and three (3) are Not Assessed. The documented uses of these plants are remarkably varied, including human food, medicine, food processing, condiments, and domestic applications. They are typically prepared by decoction or steeping from various plant parts. Notably, *Cinnamomum mercadoi* ranked first with the highest CI Index (0.57), underscoring its exceptional cultural significance and widespread use within the communities. This study fills a critical gap by going beyond simple lists of plants to provide a species-specific, use-oriented documentation. The findings of this research offer a critical baseline for crafting effective conservation policies and promoting the preservation of wild tea habitats through the active involvement of indigenous communities. The documented knowledge can be integrated into regional development strategies to support sustainable livelihoods. Furthermore, this study strongly encourages future scientific validation of the potential medical uses of these plants, particularly those with a high cultural importance index and those identified as vulnerable, to ensure their sustainable use and conservation.

Keywords: Cultural importance, diversity, ethnobotany, Mountain Province, wild tea plants

INTRODUCTION

Ethnobotanical research greatly helps in the development of more advanced plant-based remedies (Balangcod and Balangcod 2015; Fiscal 2017). Historical advancements in human life may have been influenced by the traditional knowledge of the indigenous peoples and rural communities, especially with regard to the use and conservation of natural resources. Numerous wild plants that are found all over the world are said to have a significant amount of nutrients and have long been traditionally utilized as natural treatments for a variety of illnesses (Ong and Kim 2014).

In the Philippines, wild plant species are used as folk medicine, processed into other food products, and as fresh food sources. In the Cordillera Central Range (CCR), Northern Philippines, 305 indigenous plant species are used for a variety of purposes, including medicine, food, clothing, shelter, and ceremonies (Magcale-Macandog et al. 2015). Furthermore, the indigenous peoples of Mountain Province have long been recognized to foster traditional ecological knowledge about their environment (Claudio and Abella 2024), more so with the use and management of wild plants.

Although the usage of wild tea has long been reported in other civilizations, such as China and Indonesia, the customs in the Philippines' Mountain Province are exceptionally connected to its distinct ecological and cultural environment. For millennia, the production and trading of tea have shaped economies and cultures around the world, making it the most consumed beverage after water (FAO 2022). Over 2,000 different types of tea are grown in China, the country where tea originated, and UNESCO has designated traditional processing methods as intangible cultural property (UNESCO 2021). In India, street vendors frequently sell *masala chai*, a staple beverage, while Japanese tea ceremonies, including the *cha no yu*, are praised for their artistic accuracy and awareness (Twinings 2025). Since many of these plant species are native to the Philippines and specific regions within the country, it is necessary that this essential resource be promptly documented using traditional methods of recovery and that these plants be given priority for preservation initiatives (Garcia et al. 2018).

The “wild tea" plants describe tea plants that are growing naturally in the wild rather than being grown on tea plantations. Wild tea plants play a crucial role in rural communities and undernourished regions due to their diverse applications and substantial nutritional value, providing essential micronutrients and bioactive compounds (Li et al. 2016). They can be utilized in various ways. However, the challenge lies in educating people

about the benefits of wild tea plants in their locality, helping them recognize the potential of these species, and understanding their value. Overharvesting and unsustainable harvesting practices have also contributed to the loss of species (Carter 2009), particularly wild plants.

The extensive documentation of edible wild fruits in Benguet (Chua-Barcelo 2014) and other general plant surveys (Pakipac 2010; Tacloy 2025) are ethnobotanical research in the Cordillera Administrative Region (CAR) that has shed light on the diverse plant uses of indigenous communities. However, there is still a critical knowledge gap regarding the specific ethnobotanical importance and multifaceted potential of wild tea plant species within the unique ecological and cultural landscapes of Mountain Province. The distinctive variety of wild plants that have historically been used to make beverages, as well as their particular cultural contexts and potential for sustainable economic development in various Mountain Province municipalities, were not the subject of these earlier foundational studies, despite their importance. Although there is evidence of the traditional use of these wild teas (such as *kumayo*, *tayugtog*, *gutmo*, mountain tea, and *itsa*, which were first identified in 2010 by Pakipac (2010) and later further described by Nasungan (2022) for their bioactive qualities), there is still a dearth of thorough ethnobotanical documentation on these beverage-producing species, the traditional ecological knowledge that goes along with them, and their potential and sustainability.

Despite its rich cultural heritage and biodiversity, the Philippine Cordillera has a substantial knowledge gap regarding its wild tea resources. In addition to the potential for the extinction of valuable plant species, this lack of action could also lead to the loss of the distinctive traditional ecological knowledge that is connected to these species. This research conducts an ethnobotanical investigation on wild tea plants discovered in Barlig and Bontoc, Mountain Province, in order to fill this important gap. In order to provide current, species-specific, and use-oriented documentation for these wild tea types, the strategy goes beyond simple plant inventories. The preservation of biological diversity and the region's distinctive cultural heritage depend on this specialized traditional knowledge, which also provides a strong ethnopharmacological basis that is critical for future product development and sustainable commercialization efforts.

MATERIALS AND METHODS

Study site

The study sites were selected based on ethnicity of the people, geographic location, climate type, and presence of forest areas; thus, the study was conducted in Barlig and Bontoc, Mountain Province, Philippines (Figure 1). Barlig is distinguished by its high elevation, remote location, and thick forest cover. The majority of people living in Barlig are Ifiallig, who represent the province's eastern region and are occasionally linked to the Balangao subgroup. The provincial capital, Bontoc, is more centrally located in Mountain Province at a slightly lower elevation, despite being mountainous as well. Bontoc is represented by the Ifontoks. Despite having a common Igorot identity, these discrete subgroups have localized knowledge systems, suggesting that traditional knowledge about plant resources may differ amongst municipalities because of their distinct cultural histories, localized environments, and ancestral practices (Prill-Brett 1987; Solang 2011).

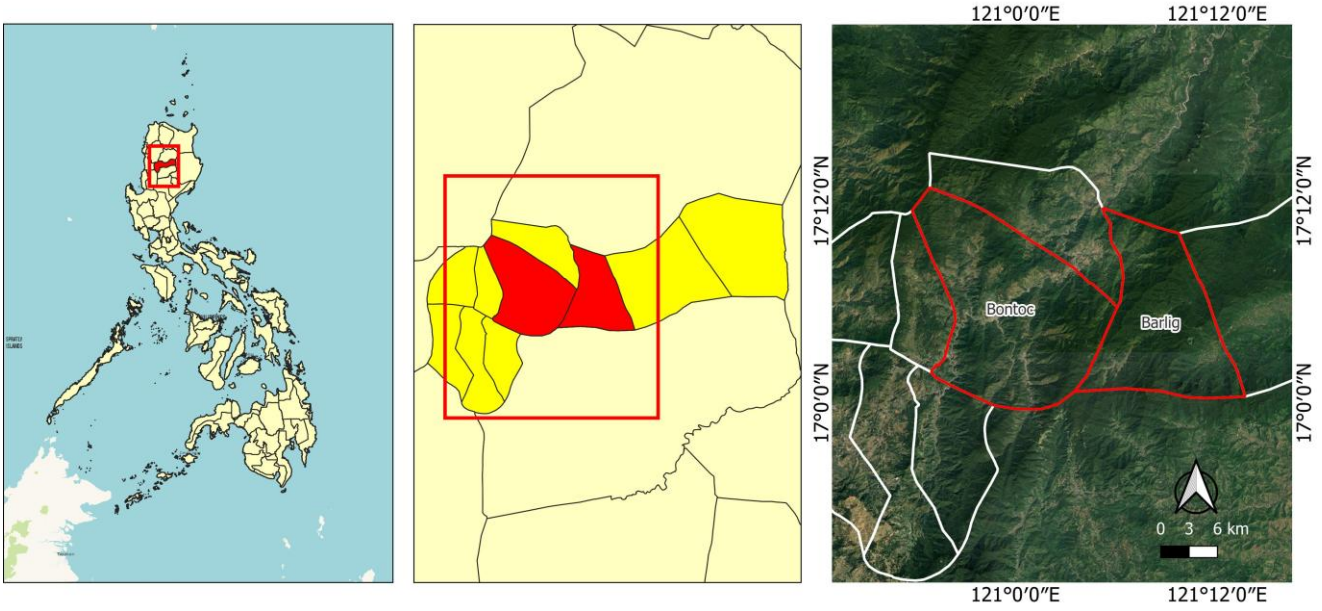

Figure 1. Map of the study sites in Barlig and Bontoc, Mountain Province, Philippines

The tea-use culture in Barlig and Bontoc, Mountain Province, is deeply ingrained and widespread. The practice of preparing and sharing wild teas is a frequent component of social interactions and daily routines, often serving as a comforting ritual and a remedy for common ailments.

As to climate, Bontoc is generally classified as type 1, which corresponds to Tropical Wet and Dry (Aw) climate in the Koppen classification system, while Barlig is type 3 (DOST-PAGASA 2019), which corresponds to the Tropical Rainforest (Af) climate in the Koppen classification system (Amfield 2025). The data were collected from January to June 2024.

Data collection

Prior to the conduct of the study, approval was first sought from the Institutional Research Ethics Committee of MPSU. A Wildlife Gratuitous Permit (DENR-CAR-01-2024) was acquired from the DENR-CAR Regional Office to gather and collect plant samples. Permits to conduct the study were also sought from the municipal mayors and barangay captains. An orientation for the barangay leaders and respondents was conducted in compliance with the National Commission on Indigenous Peoples Administrative Order No. 3 series of 2012, ensuring adherence to protocols for engaging with indigenous communities. Fieldwork was conducted from February to May 2024. A Rapid Ethnobotanical Appraisal was employed, utilizing both Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) to gather data. Data were recorded through detailed note-taking during interviews and FGDs, and with the aid of audio recordings (with explicit consent from participants) to ensure accuracy.

Before the study started, all participants were given an informed consent form that explained the goals, methods, possible risks and benefits, and their right to withdraw at any time. The participants (Table 1) were asked to read the consent form aloud and sign it.

The confidentiality and privacy of all provided information were strictly preserved. Additionally, throughout the study, local knowledge holders' invaluable inputs were recognized and valued. In order to guarantee that the research benefited the community and upheld its values of fair cooperation, their traditional ecological knowledge was handled with the highest respect, and their cultural heritage was respected.

The semi-structured method of conducting interviews was used to obtain precise information. Example questions are the following: "What plants do you use to make a tea?" and "How do you prepare the tea?". Questions about their traditional knowledge were asked, such as "How did you learn about these plants and their uses?"

Additionally, eleven FGDs were conducted per municipality, each comprising five senior citizen participants, further enriching the qualitative data collected.

Plant collection and identification

The informants assisted with field collections, as they knew where to find specific plants. Photographs of plants were also taken for documentation. Three to five branches, preferably with reproductive components (fruits and flowers), were used to create voucher specimens, which were then placed on white cartolina paper in a manner that best reflected the plant in the wild. The gathered wild tea plants were submitted to botanists, subjected to their taxonomic classifications, and, for verification of family and scientific names and conservation status, various online databases, namely Co's Digital Flora of the Philippines (Pelser et al. 2011-onwards) and World Flora Online (WFO 2022), were used. The voucher specimens were kept in MPSU Baang Campus.

Ethnobotanical quantitative analysis

The taxonomic diversity, used parts, preparation methods, conservation status, and categories of uses were counted and analyzed. Moreover, two indices were applied to furtherly estimate the importance of particular species to the local community of Barlig and Bontoc, which were named the Relative Importance Index (RI) and the Cultural Importance (CI) Index.

Cultural Importance Index (CI)

CI can be seen as the sum of the proportion of informants that mention each species use (Tardío and Pardo-de-Santayana 2008) and can be mathematically expressed as:

$$CI_s = \sum_{u=u_1}^{U_{NC}} \sum_{i=i_1}^{i_N} UR_{ui/N}$$

The highest CI Index indicates the most important species/family for a given category of usage. WTP species with the lowest CI Index were the least used or were of low importance.

Use Report (UR)

The Use Report (UR) was obtained using the formula by Tardío and Pardo-de-Santayana (2008):

$$UR_s = \sum_{u=u_1}^{U_{NC}} \sum_{i=i_1}^{i_N} UR_{ui}$$

Where:
i : Varies from only one use to the total number of uses
NU : Number of Uses
N : Total informants in the survey
UR: Use Report

Table 1. Informant demographics

Category	Description
Total number	220 key informants
Age range	40-94 years old
Gender	Male and Female
Selection Criteria	Residency of at least 10 years with experience with wild tea plants
Participant Roles	Barangay officials, hunters, farmers, homemakers, village elders

Relative Importance Index (RI).

Created by Pardo-de-Santayana (2003), this index takes into account only the use-categories— not the subcategories—using the following formula:

$$RI_s = \frac{RFC_{s(max)} + RNU_{s(max)}}{2}$$

Where $RFC_{s(max)}$ is the Relative Frequency of Citation over the maximum, i.e., it is obtained by dividing FCs by the maximum value in all the species of the survey [$RFC_{s(max)}$= FC_s/max (FC)] and $RNU_{s(max)}$ is the relative number of use- categories over the maximum, obtained by dividing the number of uses of the species by the maximum value in all the species of the survey [$RN_{s(max)}$= NU_s/max (NU)].

Statistical tools

Microsoft Excel was used in the computation and analyses of the RI and CI.

RESULTS AND DISCUSSION

Plant taxonomic diversity

A total of eighteen (18) wild tea plants (Figure 3) belonging to 13 families were documented in Barlig and Bontoc, Mountain Province (Table 2). Among the identified wild tea plant families, Ericaceae is the most represented with three species, followed by Chloranthaceae, Myrtaceae, Lauraceae, and Rutaceae with two species each (Figure 2). Also, one species belongs to the families Primulaceae, Asteraceae, Gesneriaceae, Urticaceae, Winteraceae, Rubiaceae, and Symplocaceae.

Among these wild tea species, the study found important conservation patterns. IUCN Red List of Threatened Species lists twelve of the 18 wild tea plants that have been identified as "Least Concern" (IUCN 2022). This is encouraging since it shows that their numbers are constant right now. Three species are listed as "Vulnerable," and three more are listed as "Not Assessed" because of insufficient data, highlighting the urgent need for conservation. These results highlight how crucial it is to concentrate conservation efforts, particularly for species that are at risk of extinction in the area. The existence of native and endemic species emphasizes the necessity of local preservation techniques to preserve this distinctive botanical heritage.

Top five species by CI/RI

Figure 4 shows the wild tea plants with their corresponding use value using two indices, which are the Cultural Importance Index (CI) and the Relative Importance Index (RI). *Cinnamomum mercadoi* and *Gaultheria leucocarpa* var. *cumingiana* ranked first and second, respectively. *Cinnamomum mercadoi* was mentioned by a total of 125 respondents as applicable, which is the maximum mention among all the plant species. It was employed in three different use-categories (food, medicine, and industrial/ household). The maximum number of use categories (NU_s max) mentioned for a species in the survey was three. *Cinnamomum mercadoi* topped the maximum both in the use report and in the number of use categories; thus, its rank as number one is justified. It is important to note that in the computation of the CI, the number of informants mentioning each species' use is considered. Meanwhile, RI also placed *C. mercadoi* and *G. l.* var. *cumingiana* at first and second rank. *Cinnamomum sandkuhlii* and *Dendrocnide venosa* are placed at the number three by RI and CI, respectively. RI gives more importance to *D. venosa* mainly because of its three different use-categories as previously mentioned; RI takes into account only the use-categories. Compared to *D. venosa* (3rd place- CI), although it only has two categories of uses, it has a higher Use Report and Frequency of Citation than *C. sandkuhlii.*

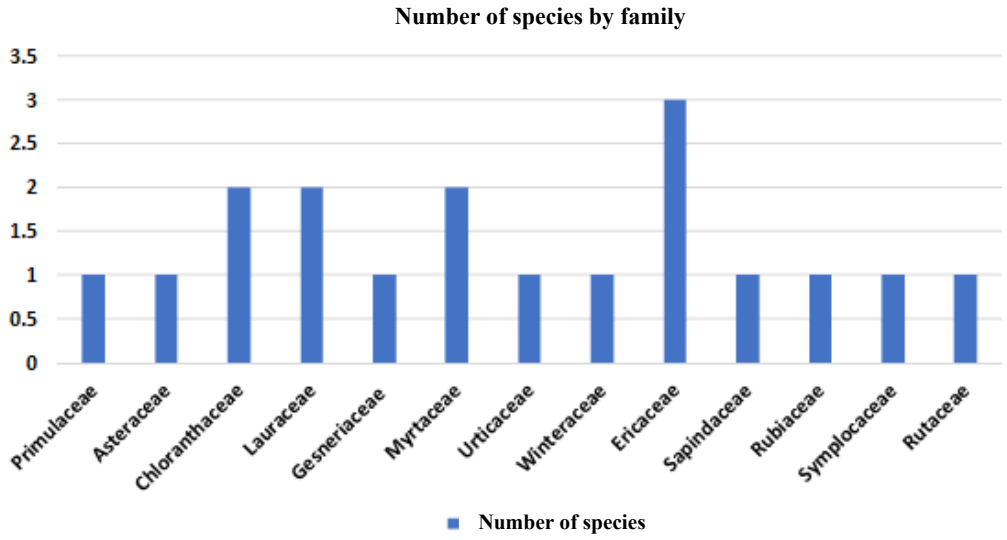

Figure 2. Number of species of wild tea plants by family in Barlig and Bontoc, Mountain Province, Philippines

Figure 3. Wild tea plants in Barlig and Bontoc, Mountain Province, Philippines. A. *Ardisia polysticta*, B. *Aster philippinensis*, C. *Chloranthus officinalis*, D. *Cinnamomum sandkuhlii*, E. *Cinnamomum mercadoi*, F. *Cyrtandra parviflora*, G. *Decaspermum blancoi*, H. *Decaspermum fruticosum*, I. *Vaccinium cumingianum*, J. *Dendrocnide venosa*, K. *Drimys piperita*, L. *Gaultheria leucocarpa* var. *Cumingiana*, M. *Murraya* sp., N. *Mussaenda benguetensis*, O. *Rhododendron quadrasianum* var. *Rosmarinifolium*, P. *Sarcandra glabra*, Q. *Symplocos whitfordii*, R. *Zanthoxylum asiaticum*

Based on the computed CI and RI index, *C. mercadoi* is the overall most important wild tea species in Mountain Province with a total of three uses (food, medicine, and industrial). It is further concluded that *C. mercadoi*, which is a tree in a life form, has many uses. *Gaultheria leucocarpa* var. *cumingiana* is the second most important, with two uses. Most species identified have 2-3 uses, which indicates that the wild tea plants have various uses. This makes these species important not only as components of forest biodiversity but also as a natural resource.

Added to the species mentioned above, *D. venosa, Sarcandra glabra*, *Chloranthus officinalis, C. sandkuhlii,* and *Drimys piperita* were also noted to be of importance in both study areas. Other tea species identified were of lower importance since these were utilized only in either of the study areas. The distribution of these species in the study areas where they are readily accessible may have further encouraged their utilization.

Table 2. Taxonomic classification and conservation status of wild tea plant species

Scientific name	Local name	Common name	Family	Plant parts used	Preparation	Health/ Culture value	Distribution status	Conservation status
Ardisia polysticta Miq.	*No local name*	Aunasin/ Tagpo	Primulaceae	Leaves	Decoction	Food (tea)/ ornament	Indigenous	Least Concern
Aster philippinensis S. Moore	*Gipas*	Philippine Aster	Asteraceae	Leaves	Decoction	Food (tea)	Endemic	Least Concern
Chloranthus officinalis Blume	*Itsa*	Tall chloranthus	Chloranthaceae	Leaves	Decoction	Food (tea), medicine	Endemic	Least Concern
Cinnamomum mercadoi S. Vidal	*Kumayu/ timpo*	Mindanao Cinnamon	Lauraceae	Leaves Bark	Decoction	Food (tea), medicine, industrial	Endemic	Vulnerable
Cinnamomum sandkuhlii Merr	*Timpo/ tungpoan*	kalingag	Lauraceae	Leaves bark	Decoction	Food (tea), medicine, industrial	Endemic	Vulnerable
Cyrtandra parviflora C.B. Clarke	*Alipo-ok*	No common name	Gesneriaceae	Leaves	Decoction	Food (tea), medicine	Endemic	Least Concern
Decaspermum blancoi S.Vidal	*Kasengseng*	Patalsik-pula	Myrtaceae	Leaves	Decoction	Food (tea)	Endemic	Least Concern
Decaspermum fruticosum (Lam.) A.J.Scott	*Mountain tea*	Brown Myrtle	Myrtaceae	Leaves	Decoction	Food (tea)	Endemic	Least Concern
Dendrocnide venosa (Elmer) Chew	*Itsa*	Silky Myrtle/ patalsik	Urticaceae	Leaves	Decoction	Food (tea), medicine	Endemic	Least Concern
Drimys piperita Hook.f.	*Tukfu/ tukbo*	No common name	Winteraceae	Roots	Decoction	Food (tea), medicine	Endemic	Least Concern
Gaultheria leucocarpa var. *cumingiana* (S.Vidal) T.Z.Hsu	*Sapal/ shupur*	Tasmannia piperita	Ericaceae	Leaves fruits	Decoction	Food (tea), medicine, condiment	Endemic	Least Concern
Murraya sp.	*Tarugcho/ talogtog/ talubatub*	Idsa/ wintergreen	Rutaceae	Leaves	Decoction	Food (tea), medicine	Endemic	Least Concern
Mussaenda benguetensis Elmer	*Anis*	Salab/ alahabi/anayen/ alahan	Rubiaceae	Leaves	Decoction	Food (tea), industrial	Endemic	Least Concern
Rhododendron quadrasianum var. rosmarinifolium (S. Vidal) H.F. Copel.	*Konna/ kon-na*	No common name	Ericaceae	Leaves	Decoction	Food (tea)	Endemic	Not Assessed
Sarcandra glabra (Thunb.) Nakai	*Kasengseng*	Vidal's Rhododendron	Chloranthaceae	Leaves	Decoction	Food (tea)	Indigenous	Least Concern
Symplocos whitfordii Brand	*Gipas/ mountain tea*	Glabrous Sarcandra Herb	Symplocaceae	leaves	Decoction	Food (tea), medicine	Endemic	Vulnerable
Vaccinium cumingianum S.Vidal	*Sagingsing*	Whitfordii Snowberry	Ericaceae	Leaves	Decoction	Food (tea)	Endemic	Not Assessed
Zanthoxylum asiaticum (L.) Appelhans	*Itsa*	orange climber	Rutaceae	Leaves	Decoction	Food (tea)	Endemic	Not Assessed

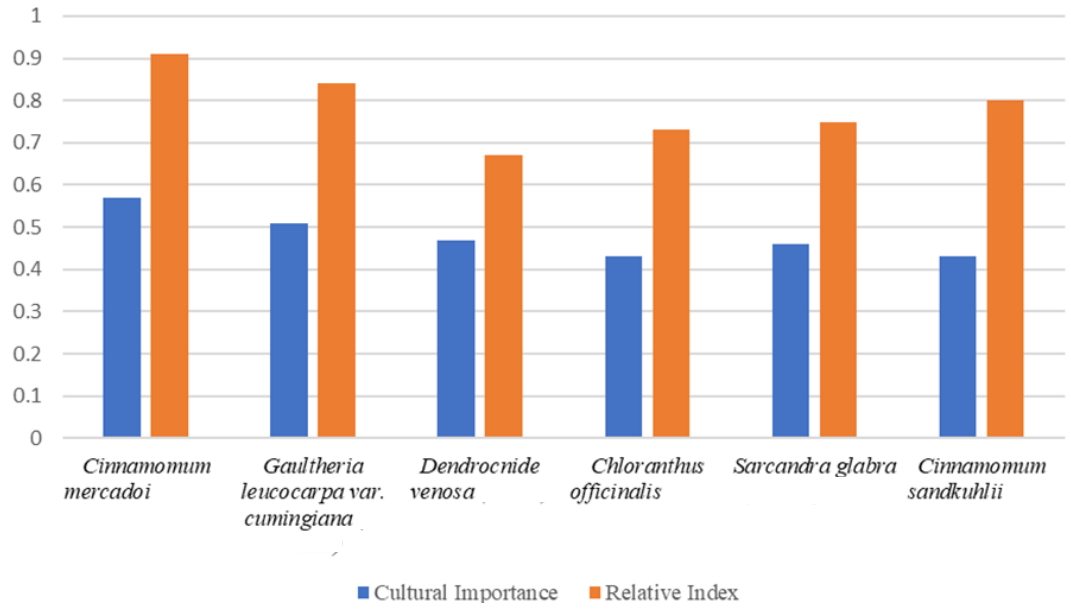

Figure 4. The wild tea plants with their Cultural Importance Index (CI) and the Relative Importance Index (RI) in Barlig and Bontoc, Mountain Province, Philippines

Key usage patterns

In terms of the method of preparation of the wild tea plants, local people apply only two (2) methods, which are decoction and steeping. Decoction (95%) is widely regarded as the most commonly used method in the preparation of beverages and medicines in Barlig and Bontoc, particularly when intended for therapeutic use (Figure 5.A). This process involves simmering medicinal plant materials such as leaves, roots, or bark in boiling water for a period of three to five minutes, after which the decoction is administered orally. In the case of *C. mercadoi* and *C. sandkuhlii*, confident respondents from Barlig noted a specialized preparation technique. This method involves a standard decoction followed by cooling, after which wine is added before consumption.

With regards to the steeping method of the wild tea plant, specifically, the *Decaspermum fruticosum* is often boiled in hot water for a minimal amount of time, and some wild tea plant species like *Zanthoxylum asiaticum* and *Murraya* sp. are prepared by putting the leaves directly in hot water without boiling. This method preserves the aromatic compounds and essential oils, which can degrade under prolonged exposure to heat, often resulting in an undesirable bitter aftertaste. Additionally, locals add some sweeteners like sugar and honey to the plant extracts to improve the flavor.

In this study, six (6) different parts of the wild tea plants were used (Figure 5.B) by the locals in Mountain Province. The most frequently used plant part was the leaf (65%), followed by bark (15%). The stems, roots, seeds, and fruits are not used frequently. The locals claim that leaves are commonly harvested for consumption because it is a tradition passed down through generations that the leaves were consumed and tested by previous generations, and that signifies safety; they dare not test other parts. The leaves were only collected to allow the plant to thrive, according to locals, which serves to preserve the species for future generations.

Cultural importance

Cultural importance denotes how important a species is in the daily life of local communities. The cultural importance of the wild tea plants in the province has not been explored. This study shows that the wild tea plants are not only used as a tea beverage but are also used for other purposes by several of the local people. The wild tea plants differ in their uses, such as food, medicine, condiments, processing, industrial/domestic purposes, and forage uses (Table 2).

Among the five use categories, food (tea beverage) has the highest percentage (75%), followed by medicine (17%), industrial (4%), ornament (1%) and condiment (1%). Only one species is used as a spice or condiment (1%), specifically *G. l. var. cumingiana*, locally called sapal/shopor. In terms of aesthetic value, *Ardisia polysticta* is the only species mentioned, while three species are used for industrial/household purposes. Furthermore, eleven species that were documented are being utilized as medicine. The result indicates that the locals mostly utilize the various wild tea plants to make tea beverages. Table 3 presents that *C. mercadoi* was noted to be of high cultural importance and was followed by *G. leucocarpa* var. *cumingiana*, *D. venosa, S. glabra*, *C. officinalis* and *C. sandkuhlii.* These species have a CI Index of above 0.40, which may indicate that these are mostly preferred tea beverages as compared to the other species. These species may have long been known for their uses, where this traditional knowledge was passed through generations. Preferences of the local folks on these species for a tea beverage may have been affected by compounds present in teas and in their organoleptic properties.

Cinnamomum mercadoi has a higher CI Index value compared to the other species used for medical purposes. It can be noted from the above table that species have low CI Index values; however, this does not mean that their significance is negligible. Few species were noted to be used for purposes other than tea beverage and medicinal home remedy, and were of very low cultural importance. Only *G. l. var. cumingiana* was used as a condiment, *A. polystica* may have been used for esthetic purposes, and *C. mercadoi* for industrial or domestic uses. However, it could be assumed based on the above data that the identified species were mainly used for tea beverage; thus, these may only be used as an alternative for other purposes.

Conservation practices

Conservation activities are being done, specifically for wild tea plants. However, during barangay general assemblies, barangay officials conduct awareness programs on forest fire prevention and protection. In collaboration with the local Bureau of Fire Protection, these activities were carried out. In an effort to stop forest fires, the locals also cleaned the dried leaves and twigs along the fire lines. In addition, the locals also prevent the tourists from getting any plant species.

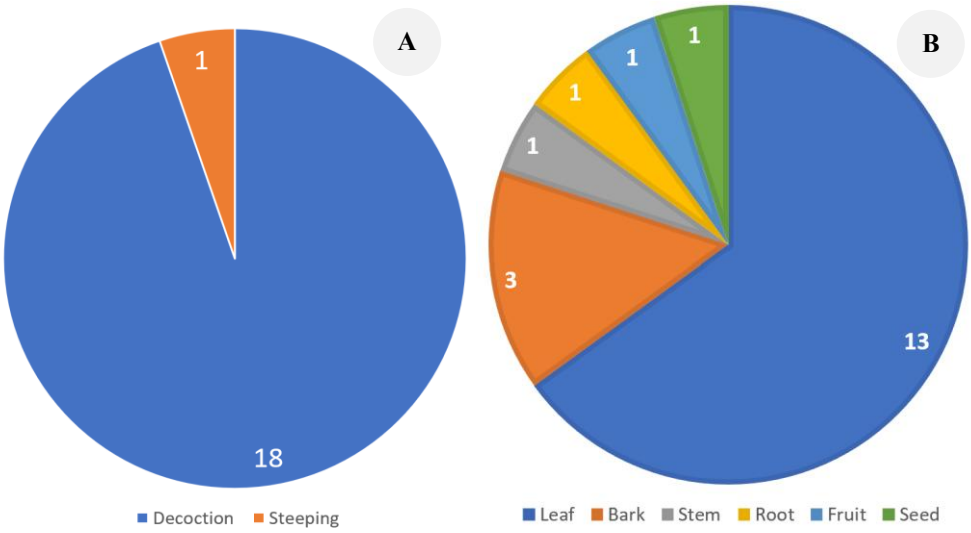

Figure 5. Wild tea plant part used and method of preparation in Barlig and Bontoc, Mountain Province, Philippines. A: Methods preparation, B. Plant part used

Table 3. Cultural importance of wild tea plants in Mountain Province, Philippines, with the Cultural Importance Index (CI) component of each use category

Species	HF	ME	CO	EU	IN	Total CI
Ardisia polysticta Miq.	0.08			0.04		0.12
Aster philippinensis S. Moore	0.01					0.01
Chloranthus officinalis Blume	0.35	0.08				0.43
Cinnamomum mercadoi S. Vidal	0.35	0.14			0.08	0.57
Cinnamomum sandkuhlii Merr	0.26	0.09			0.08	0.43
Cyrtandra parviflora C.B. Clarke	0.05	0.04				0.09
Decaspermum blancoi S.Vidal	0.18	0.04				0.22
Decaspermum fruticosum (Lam.) A.J.Scott	0.18	0.07				0.25
Dendrocnide venosa (Elmer) Chew	0.29	0.18				0.47
Drimys piperita Hook.f. (Winteracea)	0.13	0.04	0.15			0.32
Gaultheria leucocarpa var. *cumingiana* (S.Vidal) T.Z.Hsu	0.44	0.08				0.52
Murraya sp.	0.18				0.05	0.23
Mussaenda benguetensis Elmer	0.11	0.05				0.16
Rhododendron quadrasianum var. *rosmarinifolium* (S. Vidal) H.F. Copel.	0.11					0.11
Sarcandra glabra (Thunb.) Nakai	0.36	0.1				0.46
Symplocos whitfordii Brand	0.10					0.10
Vaccinium cumingianum S. Vidal	0.09					0.09
Zanthoxylum asiaticum (L.) Appelhans	0.07					0.07
Total	3.34	0.87	0.15	0.04	0.21	

Note: HF: Human Food, ME: Medicinal, CO: Condiment, AU: Aesthetic Uses, IN: Industrial and/or Domestic Use

Discussion

Plant taxonomic diversity

Eighteen wild tea plants were identified up to the species level, in terms of their endemicity or distribution status; 16 species were endemic, and 2 species are indigenous. In terms of the conservation status, most of the wild tea plants were of least concern, but some are vulnerable and not assessed based on the IUCN Red List. The findings of the study are similar to those of other ethnobotanical studies in the country, such as those of Cordero et al. (2022) and Andalan et al. (2024). Ericaceae is the most represented as it is distributed globally with 4,426 species estimated in 129 genera, which are presently classified into eight subfamilies (Stevens et al. 2004; Schwery et al. 2015). The family Ericaceae has been recorded to possess medicinal properties (Bouyahya et al. 2021). According to Garcia et al. (2018), the Philippines is known to be a biodiversity hotspot, so it is anticipated to have a multitude of plants with rich ethnobotanical knowledge.

The findings of the study can directly influence local and national policy initiatives to protect these wild tea resources. The species that have been recognized as "Vulnerable" need to be given priority attention for conservation initiatives. The IUCN Red List can be updated using the data on the "Not Assessed" species, giving a more accurate picture of their conservation status globally. A sustainable conservation strategy must empower and include local communities to safeguard their natural heritage since these plants are essential to indigenous culture. Local governments may use the results to create ordinances controlling the gathering of at-risk species and promoting sustainable actions.

Key usage patterns

The leaf is a standard plant part used as a beverage because it is easy to collect and prepare (Mesfin et al. 2014; Lemma 2017; Tefera and Yihune 2019). In tropical nations like the Philippines, leaves are an easily accessible plant part that are always available in an emergency, such as the leaves are used for medicinal purposes (Tindowen et al. 2017). Since leaves can grow and regenerate more readily than other plant parts, harvesting them is a more sustainable practice. In addition, leaves store numerous bioactive compounds (Andalan et al. 2024) and are used for the synthesis of several secondary metabolites (Hamel et al. 2018) that can be a source of biological activities (Nasungan 2022). Moreover, other plant parts were used frequently, but they also contain essential phytochemicals. Some species of wild tea have more flavor in the bark than in their leaves, like *C. mercadoi*; thus, the bark is more likely to be consumed. Pásztory et al. (2016) reported that the bark has active ingredients and is utilized by folk medicine. Other species are also consumed by their roots, one of them is the *D. venosa*. The root is not commonly harvested because the physiological activity stops when the root is harvested; thus, the entire plant is lost (Mekonnen et al. 2022).

Two methods, particularly decoction and steeping, were identified by the locals. The finding of the study corroborates the study of Daswani et al. (2011), which found that the primary method of using native plants is decoction. Typically, decoctions are consumed orally. Of all the conventional forms of preparation, they have the strongest activity and are the most rapidly absorbed by the body (Yang et al. 2009).

The consumption of tea depends on the consumer. As to claims within the locality of both Barlig and Bontoc, some prefer to consume tea without any additives, and others enjoy it with honey, sugar, or muscovado. Older folks consume it as it is, together with sweet potato, which acts as the sweetener. Milani et al. (2018) demonstrate the addition of additives such as sweeteners and flavorings to black tea, which is consumed in considerable amounts. Previous studies by Sharma et al. (2008) and Korir et al. (2014) stated that with the addition of sugar to the tea, the antioxidant content and potency are decreased.

The nature of traditional knowledge and how it is transmitted presents one important set of constraints. Knowledge is frequently specialized, despite efforts to include a variety of informants across age, gender, and roles, like the barangay officials, hunters, farmers, homemakers, and village elders. Only a very small number of people, such as certain healers or ritual practitioners, may be aware of certain plant applications or identification techniques, and their perspectives may not have been completely recorded (Berlin 1992). Additionally, as was mentioned, industrial development, shifting livelihoods, and a decrease in generations passing on information make traditional knowledge dynamic and more vulnerable to deterioration (Huntington 2000; Pieroni et al. 2011). Before the study could record it, some important knowledge on uncommon plants or their historical use may have already been lost. Despite their willingness, informants may also suffer from recall bias, unintentionally leaving out information or forgetting particular preparations or usage frequencies, especially for procedures that are not routinely carried out (Quinlan 2005).

Cultural importance of wild tea plants

Humans are inherently dependent on plants for a myriad of ecological benefits, sustenance, and medicinal purposes. Our study on wild tea plants in the Cordillera Administrative Region reveals a rich tapestry of traditional knowledge, though some species exhibit a low Cultural Importance (CI) Index. This finding, where species with restricted local distribution and single traditional uses show lower CI Index, aligns with previous observations by Chua-Barcelo (2014) concerning underutilized fruit species. This potentially highlights localized knowledge or the vulnerability of certain traditional practices to broader influences.

The result shows that among the five use categories, food (tea beverage) has the highest percentage (75%) (Table 2), followed by medicine (17%), industrial (4%), condiment (1%), and ornament (1%). According to Liu et al. (2022), with the growing demand for health and nutrition foods in recent years, plant-based beverages have become known to the community, thus wild tea plants are mainly used as a functional beverage. Plants have also

generated attention due to their pharmacological effects and phytochemical makeup (Boudou et al. 2022). Previous studies also mentioned that teas have long been utilized because they are abundant in potent bioactive compounds that could benefit human health (Nasungan 2022). Apart from being used as a tea beverage and medicine, wild plants are used as spices and food additives because of their flavoring, aroma, and preservation qualities and utilized as raw supplies for traditional domestic crafts (Al-Fatimi 2024).

The significant role of wild Cordillera plants in home medication, particularly in rural areas, has been consistently reported by various studies (Chua-Barcelo 2014; Balangcod and Balangcod 2015; Garsi 2019). Specific examples from this region underscore their therapeutic value: the roots of *D. venosa* are traditionally used by the Manobo Tribe to ease childbirth pain (Ilagan et al. 2022), reflecting a broader healing capacity for conditions like ulcers, diabetes, and inflammation (Van Valkenburg 2002; Gunardi et al. 2023). The genus *Cinnamomum*, represented by species like *C. mercadoi* and *C. sandkuhlii*, is highly valued for its anti-inflammatory, antioxidant, antimicrobial, and antidiabetic properties (Kumar et al. 2019; Wang et al. 2020; Sharifi-Rad et al. 2021). *Cinnamomum mercadoi*, specifically, serves as a remedy for digestive disorders, flatulence, headache, and rheumatism (Langenberger et al. 2009; Fuentes et al. 2010). Similarly, *S. glabra* is a natural remedy for wounds, diarrhea, cough, and skin inflammation (Bersamin et al. 2021). *Drimys piperita* Hook.f. is traditionally used for malaria and to enhance vitality (Cepeda et al. 2019), with isolated compounds exhibiting anti-diarrheal and anti-spasmodic effects (Pladio and Villaseñor 2004). The *Chloranthus* genus has a long history as a folk remedy for various ailments, including swollen boils and snake bites, possessing anticancer, anti-inflammatory, antibacterial, antiviral, and antimalarial activities (Liu et al. 2022).

The ethnobotanical importance of wild tea plants in the Philippines resonates with a broader regional trend across Southeast and East Asia, where various genera are valued for their cultural and medicinal properties. The extensive utilization of *Cinnamomum* species in traditional medicine in nations like China, Indonesia, and Vietnam is proof of this shared admiration. It is further highlighted by the intentional cultivation of a stimulating beverage tea from *Chloranthus erectus* in Indonesia and the extensive incorporation of *S. glabra* (Caoshanhu) into therapeutic teas, supplements, and household products in China (Liu et al. 2016; Hai et al. 2018; Arseniuk 2020; Zeng et al. 2021; Tang et al. 2024). This regional shared appreciation for wild tea plants as both therapeutics and culturally significant beverages—sometimes even incorporated into rituals or as a symbol of community well-being—is further highlighted by the intentional cultivation of teas in the Philippines (Taguiling and Villena 2017).

Despite their profound significance, traditional knowledge systems surrounding these wild tea plants face increasing threats. Modernization, urbanization, and a decline in intergenerational knowledge transfer pose significant risks to the continuity of these invaluable practices (Aziz et al. 2018). The loss of sophisticated knowledge on plant identification, preparation, and particular applications is a result of both a gradual decline of traditional languages and the declining participation of newer generations in traditional practice (Maffi 2005). Furthermore, environmental degradation, habitat loss, and climate change directly threaten the biodiversity of these wild plants, making their collection and sustainable use more challenging (Pimm et al. 2014). The low Cultural Importance (CI) Index observed for some species may indeed be an early indicator of this erosion, suggesting that knowledge about certain plants is becoming increasingly localized or endangered.

Therefore, exploring the diverse applications and advantages of wild edible and medicinal plants is crucial for raising awareness and developing effective conservation strategies. This aligns with the understanding in communities like Mayaoyao, Ifugao, where biodiversity is equally valued for food and medicinal purposes (Enkiwe-Abayao 2002). Documenting these traditional practices is not only vital for preserving cultural heritage but also for identifying potential bioresources for future health and economic benefits, while ensuring that the rights and intellectual property of local knowledge holders are respected and protected.

Conservation practices

The conservation status of the eighteen wild tea plant species identified in the study is largely encouraging, with most being classified as "Least Concern" on the IUCN Red List. This result is consistent with similar ethnobotanical assessments carried out throughout the Cordillera, which indicate that not all wild plant resources are heavily used for customary purposes (Magcale-Macandog et al. 2015). Instead, the utilization patterns appear to be significantly influenced by a plant's availability and accessibility, with communities primarily gathering species that are common and found in close proximity. This selective harvesting, driven by convenience, can inadvertently act as a natural conservation mechanism, reducing pressure on rarer or more geographically remote species.

However, despite the current "Least Concern" status for many species, ongoing conservation measures remain critical, particularly for frequently utilized wild plants, to ensure their long-term sustainability (Abdusalam et al. 2020). Across the Philippines and other Asian countries, a multifaceted approach to plant conservation is being adopted, integrating both modern scientific methods and traditional ecological knowledge. In-situ conservation efforts include the establishment and effective management of protected areas and community-managed forests, where local communities actively participate in safeguarding plant diversity through sustainable harvesting practices and resource management plans (Pulhin and Pulhin 2003; Tauli-Calugan 2025). This aligns with the understanding in communities across the Cordillera, such as in Mayaoyao, Ifugao, where biodiversity is valued equally for its food and medicinal purposes (Enkiwe-Abayao 2002). Ex-situ conservation complements these efforts through botanical gardens (Tobias et al. 2019). Therefore, documenting these

traditional practices is not merely about preserving cultural heritage; it is a vital step toward identifying potential bioresources for health and economic benefits, while simultaneously ensuring that the rights and intellectual property of local knowledge holders are respected and protected through a collaborative, community-based conservation model.

Furthermore, the revitalization and documentation of Traditional Ecological Knowledge (TEK) are paramount. Indigenous communities in the Philippines, for instance, often possess intricate knowledge of plant life cycles, optimal harvesting periods, and sustainable regeneration techniques, which are vital for the continued existence of wild tea plant populations (Afuang et al. 2021). Promoting intergenerational knowledge transfer and supporting community-based conservation initiatives are key strategies to empower local communities in safeguarding their botanical heritage. Policy frameworks and legal instruments also play a crucial role in regulating access to and use of wild plant resources, preventing over-exploitation and ensuring equitable benefit-sharing (ASEAN Centre for Biodiversity 2023). By integrating these diverse conservation practices, it is possible to balance the traditional utilization of wild tea plants with their ecological preservation, ensuring their availability for future generations and sustaining the cultural practices linked to them.

In conclusion, Barlig and Bontoc, Mountain Province, are naturally occurring locations with diverse highly beneficial wild tea plants. Thirteen families of eighteen (18) wild tea plants were identified in the Mountain Province's Barlig and Bontoc. The different wild tea plants were being utilized for various cultural importance, particularly as human food, medicine, aesthetics, condiments, and industrial material or decoration. Among the cultural importance mentioned, most of the wild tea plants were used as human food, specifically as a beverage, and most of these wild teas are shrubs. *Cinnamomum mercadoi* has the highest cultural importance index and relative importance index among the eighteen wild tea plants. In addition, leaves are the common plant part being used, and the methods of preparation are decoction and steeping. Locals have conservation practices being done to prevent the degradation of the wild tea plants, but few people are taking part in the conservation efforts being made.

Furthermore, plant resources can also be depleted if they are continuously harvested without effective conservation and management. Thus, it is possible to encourage and recommend biodiversity conservation policies to preserve the plants and their native habitats. Digital archives or field guides for the wild tea species should be created to systematically document and archive traditional ecological knowledge. Educational programs should be made that actively engage younger generations to teach them about the importance of wild tea plants and the traditional knowledge tied to them. These programs can cultivate a sense of pride and stewardship, ensuring the knowledge is passed on.

Building on the fundamental ethnobotanical knowledge acquired from the present study, a number of interesting research possibilities emerged. The results of the study may be a basis for conducting studies on the different wild tea plants in terms of their potential biological activities, such as antioxidant and antimicrobial properties, phytochemical screening, particularly species with high cultural importance index, and investigating these plants' deeper sociocultural importance in addition to their practical applications.

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Ethnobotany and traditional food plant knowledge among the Malay community of Kuantan Singingi District, Riau, Indonesia

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Abstract. *Hafizah N, Chikmawati T, Djuita NR, Purwanto Y. 2025. Ethnobotany and traditional food plant knowledge among the Malay community of Kuantan Singingi District, Riau, Indonesia. Asian J Ethnobiol 8: 271-290.* The Malay community in Kuantan Singingi District, Riau Province, Indonesia, is known for its unique culture and cuisine. However, their local knowledge and wisdom regarding the use of food plants have not been documented. This study aims to change that, documenting and analyzing diversity, identifying the local importance of species, and supporting sustainable biodiversity conservation. The research was conducted across five villages in Kuantan Singingi District, using open-ended, semi-structured, and structured interviews with 107 informants selected through purposive and snowball sampling methods. Data were analyzed to show Use Value (UV), Relative Frequency of Citation (RFC), Index of Cultural Significance (ICS), and Important Value Index (IVI). A total of 167 plant species belonging to 55 families were recorded, dominated by Fabaceae (13 species). Trees (40.12%) and herbs (33.53%) were the most common growth forms, with fruits (44.74%) and leaves (22.11%) as the main parts used. *Cocos nucifera* exhibited the highest UV, RFC, and ICS, reflecting its central cultural and culinary role. Knowledge was found to be influenced by gender, age, and occupation, with women and older generations serving as primary custodians. This study provides the first comprehensive documentation of food plant knowledge in Kuantan Singingi. It underscores the need for conservation strategies, intergenerational knowledge transfer, and integration of ethnobotanical knowledge into education to sustain both biodiversity and cultural heritage.

Keywords: Index of Cultural Significance, Malay food plant knowledge, Riau ethnobotany, Relative Frequency of Citation

INTRODUCTION

Interactions between local communities and the natural environment have been ongoing for a long time, especially since they began settling and cultivating plants to meet their food and medicinal needs (Santos et al. 2022). Food plants play an important role in daily lives, not only as a source of nutrition but also as a reflection of cultural identity. The unique processing of food plants is closely linked to cultural traditions passed down through generations (Nurainas et al. 2022), becoming an integral part of the cultural identity of an ethnic group in a particular region. In certain circumstances, such as food scarcity, local food plants become an integral part of traditional food systems, ensuring food security and self-sufficiency (Yangdon et al. 2022).

The Malay community that inhabits Kuantan Singingi District, Riau, Indonesia, is one example of a Malay community that has high food security and independence (BPS 2023). It is reflected in the largest rice productivity in Riau Province, a cultural icon of the Malay community in Indonesia, located in an area on the east coast of Sumatra (Yusri et al. 2022). In addition to excelling in rice productivity, the Malay community inhabiting Kuantan Singingi District has a unique culture that develops as an acculturation between Malay and Minangkabau cultures (Saputra 2007). This cultural identity is reflected in the processing of non-cultivated crops into traditional fermented foods (Maslami et al. 2024) and the cultivation of local rice cultivars (Marlina et al. 2023).

Currently, knowledge about local food plants is declining, particularly due to urbanization, which limits community access to local plants and shifts consumption patterns toward modern instant foods (Saupi et al. 2020; Nguanchoo et al. 2025). Additionally, habitat loss caused by land conversion for oil palm plantations continues to increase, especially in Riau Province. This situation threatens the survival of food crop species and diminishes local knowledge in the region. Therefore, an exploration of the relationship between community culture and the use of local food crops (Moteetee et al. 2019) needs to be carried out to ensure and maintain food security, one of which can be done by encouraging the diversity of food sources (Hidayati et al. 2015).

The Malay community's traditional knowledge of using plant diversity has only been passed down orally, raising concerns about its potential loss over time. Therefore, documenting this local wisdom through ethnobotanical research is essential. The most recent ethnobotanical studies on food plants within the Malay group in Riau remain limited. So far, only two studies have recorded how the Malay community in Riau uses plants. The Malay

community in Kampar Kiri Hulu uses 76 species of plants (Susandarini et al. 2021), and in Rokan Hulu uses 40 species (Wahyuni et al. 2021). However, ethnobotanical research on the food plants of the Malay community in Riau is still limited and poorly documented compared to other areas, such as in Belitung District (Chikmawati et al. 2023), and other border communities, such as the Minangkabau in West Sumatra (Nurainas et al. 2022; Syamsuardi et al. 2022; Agesti et al. 2023; Suwardi et al. 2023).

Therefore, the local wisdom of the Malay community in Kuantan Singingi and its food diversity require urgent documentation. This study is the first comprehensive ethnobotanical research of food conducted among the Malay community in Riau, particularly in Kuantan Singingi District. This study aims to (i) inventory and characterize food plant species utilized by the Malay community in Kuantan Singingi District; (ii) assess the local importance of these species, and (iii) analyze the management and sustainable development of food plants.

MATERIALS AND METHODS

Study area

This research was conducted from July 2024 to January 2025 in Kuantan Singingi District, Riau Province, Indonesia, which is located between 0°00 LU-1°00 LS and 101°02' East-101°55 East. Kuantan Singingi District has a tropical climate with annual rainfall ranging from 60.21 to 652.71 mm per month, and experiences 8 to 24 days of rain per month. The highest rainfall occurs in December, while the lowest rainfall occurs in September (BPS 2024). The research data were collected from five villages in different sub-districts, each with varying regional characteristics and traditions, ranging from lowland (Kinali, Pulau Kumpai, and Simpang Tiga) to flat-hilly areas (Koto Sentajo and Muara Lembu) (Figure 1).

Informant selection

A total of 107 informants (37 men and 70 women) aged 16 to 87 years were chosen. Community leaders and individuals with extensive knowledge of the diversity and utilization of food plants and landscape units were identified as key informants through purposive sampling (Neuman 2014). Meanwhile, members of the general public familiar with and utilizing food plants for various purposes in their daily lives were selected as general informants through snowball sampling (Naderifar et al. 2017).

Before conducting the research, official written permission was obtained from the local government of Kuantan Singingi District. Prior to starting data collection in each village, permission was secured from village officials and traditional elders. All interviews with informants were conducted directly between the researcher and the informant. The informants' willingness to participate was confirmed before each interview. The data collection process was halted once data saturation was reached, indicating that no new significant information was obtained when additional informants were included.

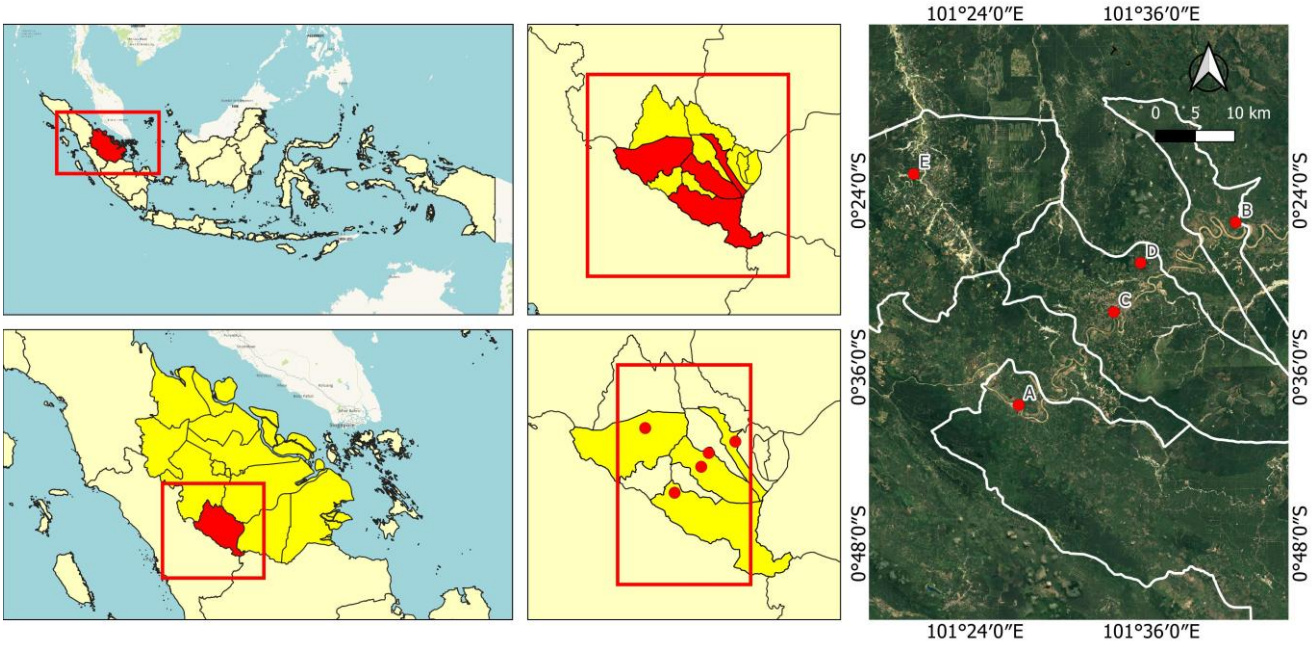

Figure 1. Map of research location in Kuantan Singingi District, Riau, Indonesia. A. Kinali, B. Pulau Kumpai, C. Simpang Tiga, D. Koto Sentajo, and E. Muara Lembu

Data collection

Ethnobotanical data, both qualitative and quantitative, were collected through open-ended, semi-structured, and structured interviews using questionnaires. The information collected included the diversity of food plant species, local names, parts used, processing methods, utilization methods, harvest locations, frequency of utilization, cultural value, and social value.

In addition to interviews, another method used was field observation with local informants in their natural habitat to identify plants directly. Plant species that could not be identified during field observations were collected for herbarium preparation using the standard method of Das (2020). Herbarium specimens were identified at the Botany Laboratory of the University of Riau by comparing them to plant identification books by matching the morphological characteristics of the specimens with two reference books, "Flora of Java" (Backer and Bakhuizen van den Brink 1968) and "Malesian Seed Plants: Spot-Characters" (Van Balgooy 1997). The scientific names were verified using online databases, including the Global Biodiversity Information Facility (GBIF) (https://www.gbif.org/), Plant of the World (https://powo.science.kew.org/), and World Plant Online (WFO) (https://wfoplantlist.org/plant-list).

Data analysis

Qualitative data were analyzed through species classification, categorized based on family, growth habits, use categories, plant parts used, and preparation methods. To improve the interpretability of the results, data were further visualized using pictures and graphs, while heat maps highlighted prominent growth habits and parts used patterns. Meanwhile, quantitative data were analyzed using indices such as Use Value (UV), Relative Frequency of Citation (RFC), Index of Cultural Significance (ICS), and Importance Value Index (IVI) (Table 1). The IVI data of a plant species is used to determine conservation strategy by comparing the IVI with the ICS value (Table 2). Quantitative analysis was performed using Excel, frequency analysis, and basic descriptive statistics to summarize and interpret the findings, with the results presented in tabular form.

RESULTS AND DISCUSSION

Food plants diversity

This study recorded a total of 167 plant species, belonging to 117 genera and 55 families, as food sources (Table S1). The most common plant family used is Fabaceae (13 species), followed by Rutaceae (9 species), Anacardiaceae, Cucurbitaceae, Myrtaceae, Poaceae, Solanaceae (8 species), Zingiberaceae (7 species), and other families (1-5 species) (Table 3). Food plants used by the Malay community in Kuantan Singingi District consist of both cultivated (100 species) and non-cultivated (67 species) plants.

Table 1. Summary of quantitative data index used in this study

Index	Formula	Purpose	Sources
Relative Frequency of Citation (RFC)	RFC = ΣFC / N	Indicated how often a species is mentioned by informants or its popularity among the community	Bano et al. (2014)
Use Value (UV)	UV = ΣU / N	Indicated the relative importance of each species based on the number of uses reported by the informant	Phillips et al. (1994)
Index of Cultural Significance (ICS)	ICS = q x i x e	Indicated the importance of a species in a cultural context, based on three aspects: quality of use, intensity of use, and the level of community preference for the plant.	Helida et al. (2015)
Importance Value Index (IVI)	IVI = RF + RD + RDo	Indicated species availability in a landscape	Ismail et al. (2017)

Note: FC: Number of informants who mentioned a species, N: Total number of informants, U: Number of uses mentioned by informants for a plant species, q: Quality value, representing the total use of a plant species, i: Intensity value, referring frequency of utilization, e: Exclusivity value, indicating the level of exclusivity of use, RF: Relative Frequency, RD: Relative Density, RDo: Relative Dominance

Table 2. Classification of conservation strategies based on IVI and ICS scores

Comparison category		Conservation
IVI	ICS	
Moderate/high	Moderate/high	Maintaining habitat and the availability of species
Low/moderate	High	Cultivating species
High	Low	Assessing and developing other potentials
Low	Low	Cultivating, studying, and developing another potential

Note: ICS: Index of Cultural Significance, IVI: Importance Value Index, Source: Dewi et al. (2016)

The number of food plant species found in this study was higher than in two previous studies in the Riau, namely 76 species in the Malay community in Kampar Kiri Hulu (Susandarini et al. 2021) and 40 species in Rokan Hulu (Wahyuni et al. 2021). However, this number is still lower than the findings in the Malay community in Belitung District, which reached 181 species (Chikmawati et al. 2023). The high proportion of cultivated species compared to non-cultivated species reflects agroforestry management strategies that ensure sustainable food supplies (Suwardi et al. 2025). Several non-cultivated plant species used by the Malay community in Kuantan Singingi as food are shown in Figure 2.

The Malay community in Kuantan Singingi District utilized the Fabaceae family for a variety of uses, including fruits, vegetables, side dishes, and spices. The Fabaceae family is the most widely used plant family as a food source globally, with around 640 species recorded (Ulian et al. 2020). This dominance is also reflected in Southeast Asia, including in Thailand (Phatlamphu et al. 2021; Nguanchoo et al. 2025), Myanmar (Shin et al. 2018), and Indonesia (Sujarwo et al. 2016; Agesti et al. 2023).

The number of food plant species used varies among villages. The highest plant species diversity was found in Koto Sentajo Village (136 species), which is located near a protected forest area, that still depends on local food plants. At the same time, people in Simpang Tiga use fewer plant species (108 species) than in the other villages. Simpang Tiga is located in an urban area that has been exposed to modern lifestyles. As a result, the residents do not rely on food plants because they can easily access animal-based and fast food. Additionally, the expansion of urban areas has led to a loss of access to food plants, especially non-cultivated ones (Phatlamphu et al. 2021).

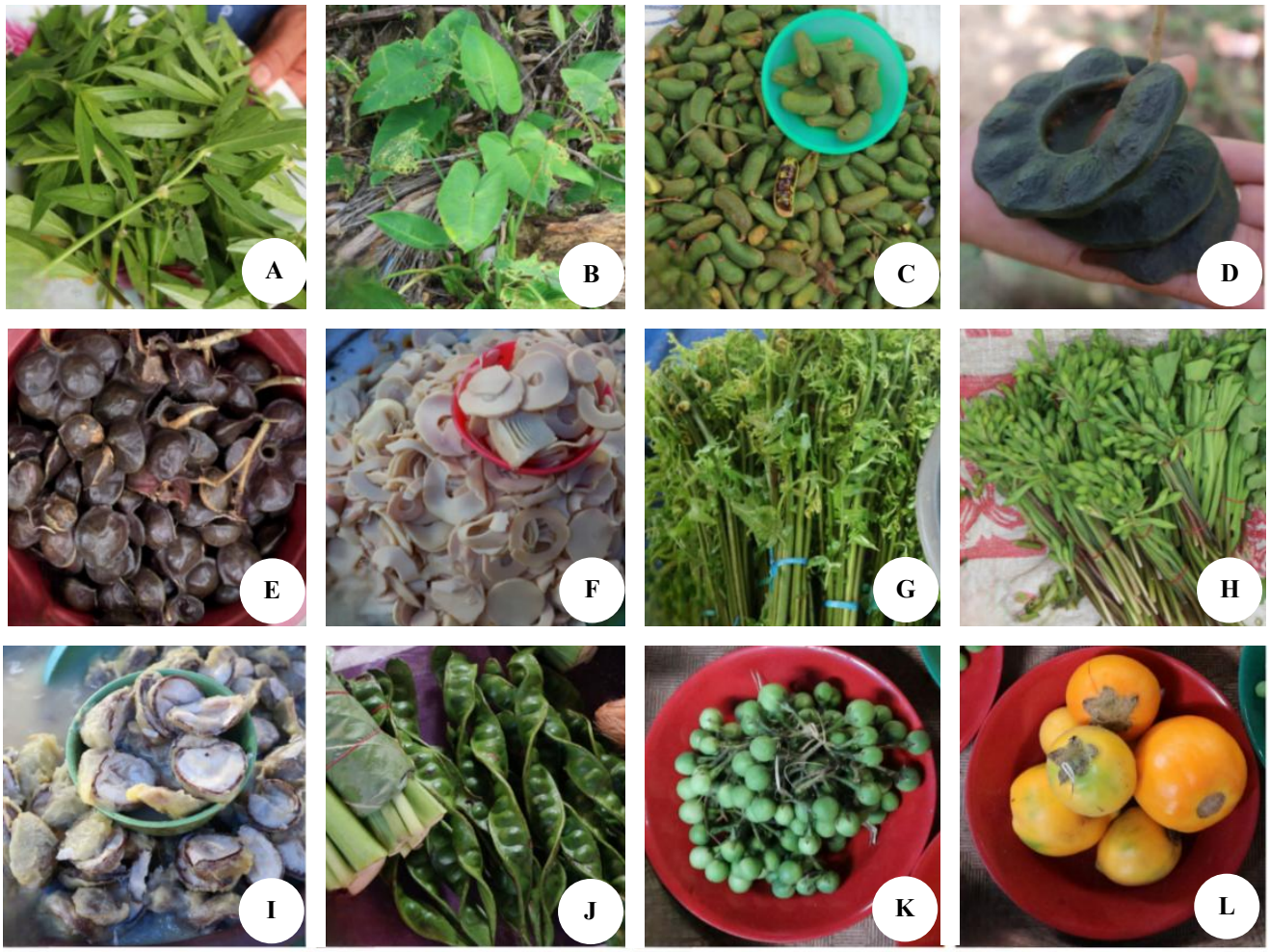

Figure 2. Non-cultivated food plant species used by the Malay community in Kuantan Singingi District, Riau, Indonesia. A. *Alternanthera sessilis* (L.) DC, B. *Apoballis mutata* (Scort. ex Hook.f.) S.Y.Wong & P.C.Boyce, C. *Archidendron bubalinum* (Jack) I.C. Nielsen, D. *Archidendron bigeminum* (L.) I.C.Nielsen, E. *Archidendron jiringa* (Jack) I.C. Nielsen, F. *Bambusa vulgaris* Schrad. ex J.C.Wendl., G. *Diplazium esculentum* (Retz.) Sw., H. *Limnocharis flava* (L.) Buchenau, I. *Pangium edule* Reinw., J. *Parkia speciosa* Hassk., K. *Solanum torvum* Sw., L. *Solanum virginianum* L

Table 3. Plant families utilized by the Malay community in Kuantan Singingi District, Riau, Indonesia

Family	Number of species
Fabaceae	13
Rutaceae	9
Anacardiaceae, Cucurbitaceae, Myrtaceae, Poaceae, Solanaceae	8
Zingiberaceae	7
Phyllanthaceae	6
Arecaceae, Sapindaceae	5
Amaranthaceae, Amaryllidaceae, Apiaceae, Araceae	4
Clusiaceae, Euphorbiaceae, Lamiaceae, Malvaceae, Meliaceae, Moraceae, Passifloraceae	3
Annonaceae, Asteraceae, Brassicaceae, Convolvulaceae, Fagaceae, Lauraceae, Melastomataceae, Musaceae, Oxalidaceae, Piperaceae, Rubiaceae	2
Achariaceae, Alismataceae, Apiaceae, Araliaceae, Asparagaceae, Athyriaceae, Blechnaceae, Bromeliaceae, Cactaceae, Caricaceae, Dioscoreaceae, Gnetaceae, Menispermaceae, Moringaceae, Muntingiaceae, Myristicaceae, Pandanaceae, Pontederiaceae, Sapotaceae, Schisandraceae, Theaceae, Vitaceae	1
Total number of families	55

Use categories

The food plants utilized by the Malay community in Kuantan Singingi District, Riau, Indonesia are categorized into two main categories, namely staple foods and supplementary foods. Staple foods are the main foods that are the primary source of energy for humans. These foods usually contain high amounts of carbohydrates and are consumed daily as the largest part of the diet. On the other hand, supplementary foods are food plants consumed as complements to staple foods to meet other nutritional needs, such as protein, vitamins, and minerals. The supplementary food plants utilized by the Malay community can be grouped into six categories, namely vegetables (69 species), fruits (59), spices (42), snacks (14), beverages (12), and side dishes (7) (Figure 3). The highest utilization category is vegetables, followed by fruits and spices. A similar result was reported on the Malay Community in Kampar Kiri Hulu by Susandarini et al. (2021).

Staple foods vary from one region to another depending on natural conditions, culture, and food availability. The Malay community in Kuantan Singingi District has the same staple food source, namely rice (*Oryza sativa* L.). Thirty-one local rice cultivars are still cultivated by the Malay community, which are classified into two main groups based on their texture. The first group is non-glutinous rice (*O. sativa*), locally known as *padi corai*, including *sokan*, *bujang merantau*, *bujang di rantau*, *kuniak*, *putiah*, *adam*, *ros*, *gondok*, *limbayang*, *katiok putiah*, *sirondah putiah*, *sarondah kuniang, sarondah merah, sarondah sira, singgaro merah*, *singgam putiah*, *singgam kuriak*, *batik lembayuang*, *batang piaman*, *lama*, *rondah sira, rondah putiah*, and *pandan wangi*. The second group is glutinous rice (*O. sativa* var. *glutinosa*), locally known as *padi puluik*, which includes *puluik bangkinang*, *puluik merah*, *puluik bungo belimbiang*, *puluik hitam*, *puluik solok*, *puluik benai*, *puluik kuning,* and *puluik karate*.

People traditionally distinguish local rice cultivars based on taste, color, texture, and grain shape. People in Kuantan Singingi District prefer a type of rice known as pera (fluffy rice), which is pure white and fragrant (Marlina et al. 2023). The Malay community in Kuantan Singingi District cultivates more local cultivars because they have a better taste, color, and texture. For example, the *putiah* is known as pure white rice, and the *pandan wangi* is famous for its fragrant pandan aroma. In addition, local rice cultivars are more adaptive to the environmental conditions in their village than modern cultivars. Kuantan Singingi District often experiences crop failures due to annual flooding and the expansion of oil palm plantations. Local cultivars can be used as an alternative crop to avoid crop failure. For example, the *sirondah putiah* and *sarondah merah* cultivars are resistant to drought stress, while the *ronda putiah* cultivar is able to adapt to fluctuations in water availability (Ezward et al. 2023).

Vegetables play a central role in Malay traditional cuisine. The Malay community has a diverse range of vegetable dishes and methods of preparation. Most of the vegetables used in traditional cuisine come from non-cultivated plants because people in the past had limited knowledge of agriculture. Several non-cultivated species commonly used as vegetables in traditional cuisine include *Apoballis mutata* (Scort. ex Hook.f.) S.Y.Wong & P.C.Boyce (*salimpek*), *Bambusa vulgaris* Schrad. ex J.C.Wendl. (*buluah*), *Diplazium esculentum* (Retz.) Sw. (*paku*), *Limnocharis flava* (L.) Buchenau (*kalayau*), and *Pangium edule* Reinw. (*samauang*).

The high utilization of fruit reflects their nutritional richness and economic value. Fruit is usually consumed directly when ripe, but its availability varies seasonally depending on the amount of fruit present in the environment. The Malay community in Kuantan Singingi prefers non-cultivated fruits, especially those with sour or sweet flavors, such as *Baccaurea motleyana* (Müll.Arg.) Müll.Arg. (*rambai*), *Baccaurea macrocarpa* (Miq.) Müll.Arg. (*tampui*), *Baccaurea polyneura* Hook.f. (*sijontiak*), *Mangifera caesia* Jack (*kemang*), *Mangifera odorata* Griff. (*kuini*), *Mangifera sumatrana* Miq. (*pauh*), *Mangifera laurina* Blume (*polam*), *Nephelium maingayi* Hiern (*pudung tunjuak*), and *Nephelium ramboutan-ake* (Labill.) Leenh. (*pelasan*). However, the fruits are becoming increasingly rare due to their reliance on natural habitats and lack of cultivation efforts. In particular, *M. caesia* was categorized as Near Threatened (NT) by the IUCN in 2021, with population declines attributed to habitat loss driven by plantation expansion and deforestation (Ganesan 2021).

Spices commonly used in various Malay traditional dishes are characterized by a combination of spicy, savory, and sour tastes. *Capsicum annuum* L. (*lado merah*) and *Capsicum frutescens* L. (*lado rawit*) are spice plants that provide a spicy taste. At the same time, *karambial* (*Cocos*

nucifera L.) adds savory flavors and thickens the texture of the dish. In addition, the Malay community in Kuantan Singingi District also utilizes the fruit of non-cultivated plants to impart a sour and fresh taste, such as *Averrhoa bilimbi* L. (*belimbing boreh*), *Garcinia xanthochymus* Hook.f. ex T.Anderson (*asam kandih*), *Garcinia atroviridis* Griff. ex T.Anderson (*asam galugua*), and *Solanum virginianum* L. (*torouang asam*). *Solanum virginianum* is commonly used in Malay dishes, such as *asam podeh* (a soupy dish with a sour and spicy taste). This knowledge is similar to that of the Malay community in Siak, Riau Province, Indonesia (Suprianti et al. 2017) and Sarawak, Malaysia (Jais 2016). Spices are also utilized by the Malay community to enhance aroma and eliminate unpleasant odors, particularly from meat or fish. *Polyscias scutellaria* (Burm.f.) Fosberg (*tapak leman*) leaves are used in goat curry, while *Ocimum tenuiflorum* L. (*ruku-ruku*) leaves are used in fish curry.

Snacks are supplementary foods consumed outside of main meal times, usually to stave off hunger. The Malay community of Kuantan Singingi District uses 14 species of plants as sources of snacks, which generally contain carbohydrates, as they serve as additional sources of energy. Two species of snack foods have potential as alternative foods during times of food scarcity, namely *Dioscorea hispida* Dennst. (*gadung*) and *Metroxylon sagu* Rottb (*rumbio*). Tubers of *D. hispida* contain 58.3-71.9% carbohydrates (Saleha et al. 2018). This species is used by the Bentong community in South Sulawesi as a source of carbohydrates during the dry season (Amboupe et al. 2019). Meanwhile, *M. sagu* has potential as an alternative local food source in Kuantan Singingi District, especially when rice crops fail due to flooding. This species is well-adapted to swampy and marginal lands, and it can thrive under flooded conditions, where other carbohydrate-producing crops struggle to grow (Azhar et al. 2022). Among all starch-producing plants worldwide, *M. sagu* has the highest starch productivity, ranging from 86.50 to 97.70%. This species has been a staple food for thousands of years in Southeast Asia and the Pacific, and it is still the main source of carbohydrates in Papua New Guinea (Duque et al. 2018).

Beverage plants include *C. nucifera* and *M. odorata,* commonly processed into a Malay traditional drink, known as *laksamana mengamuk*. This beverage is made from the fruit of *M. odorata* mixed with raw *C. nucifera* milk. The fruit of *M. odorata* has a soft, juicy pulp and a sweet taste (Juliantari et al. 2021). This beverage is only served during the *M. odorata* fruit season because any other fruit cannot replace the flavor and aroma of the fruit.

Side dishes are supplementary foods that serve to supplement staple foods as sources of protein, fat, and various complementary nutrients. The community uses seven plant species as sources of plant-based side dishes, which generally consist of protein-rich grains, including *Arachis hypogaea* L. (*kacang tanah*), *Archidendron bigeminum* (L.). I.C.Nielsen (*keliling*), *Archidendron jiringa* (Jack) I.C.Nielsen (*joriang*), *Archidendron bubalinum* (Jack) I.C.Nielsen (*kabau*), *Leucaena leucocephala* (Lam.) de Wit (*potai cino*), *Parkia speciosa* Hassk. (*potai*), and *P. edule* (*samauang*). The consumption of these plant-based side dishes is seasonal because their availability depends on the season and environmental conditions.

Growth habit, parts used, and habitat

Growth habit food plants utilized by the Malay community are trees (40.12%), herbs (33.53%), shrubs (13.17%), climbers (8.38%), creepers (3.59%), and lianas (1.20%) (Figure 4.A). The Malay community in Kuantan Singingi District most widely utilizes plants with a tree growth habit, due to high availability in various landscapes such as gardens, forests, and yards, and provides a variety of consumable parts, including fruits, leaves, seeds, flowers, and bark.

The Malay community in Kuantan Singingi utilizes nine plant parts, namely fruits (44.74%), leaves (22.11%), seeds (11.58%), flowers (7.89%), tubers (4.74%), stems, shoots (3.16% each), rhizomes (2.11%), and bark (0.53%) (Figure 4.B). The most utilized plant part is the fruit, followed by leaves. Fruits are widely used as sources of food, in the categories of fruits, vegetables, spices, and beverages. They are typically consumed fresh when ripe or used as vegetables when still young, for example, the young fruit of *Artocarpus heterophyllus* Lam. (*cubodak*), *Musa* x *paradisiaca* L. (*pisang*), and *Carica papaya* L. (*katelo*). Leaves are the second most commonly consumed plant part because of their year-round availability, as they are not dependent on specific seasons. Leaves are commonly consumed fresh by the Malay community as *ulam*, a type of traditional salad, typically served fresh or lightly cooked. This knowledge is similar to that of the Malay community in Malaysia (Awang-Kanak et al. 2018).

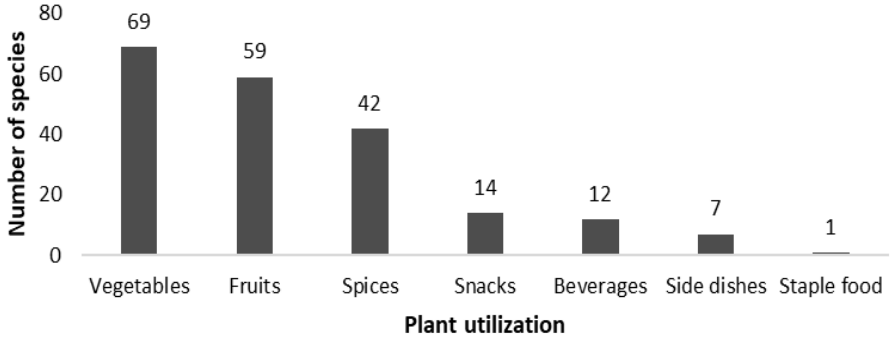

Figure 3. Categories of plant utilization by the Malay community in Kuantan Singingi, Riau, Indonesia

The heat map shows that the most utilized part of the tree habitus is the fruit (45 species), while in the herbaceous habitus, the most commonly used part is the leaves (23 species) (Figure 5). This pattern reflects the preference of the Malay community for harvesting plant parts that are easily accessible, non-destructive, and have high nutritional value. The Malay community generally harvests fruits and leaves manually without damaging the plant structure. A similar harvesting pattern is also found among the Minangkabau community in West Sumatra, who selectively harvest non-cultivated fruits to maintain sustainability (Suwardi et al. 2023).

Malay people utilize plants originating from 6 types of landscapes: yard (*laman*), *polak* (short rotation plantation), garden (*kobun*), agroforestry, rice field, and forest (*rimbo*) (Figure 6). Most people in Kuantan Singingi District found food plants in yards (115 species). Yards play an important role in meeting households' daily food needs and improving food security through plant diversification. Globally, yards are recognized as an important contributor to food security, household nutrition, and rural livelihoods (Ofosu-Bamfo et al. 2023).

Preparation methods

The food plants consumed by the Malay community in Kuantan Singingi District are processed using eight preparation methods, including cooked (47.42%), raw (38.03%), boiled (7.04%), roasted (2.82%), fermented (2.35%), soaked (1.41%), grated and burned (0.47% each) (Figure 7). These diverse methods are the result of accumulated knowledge, trials, and personal experiences that are passed down from one generation to the next.

Cooking is the most common preparation method among the Malay community, especially for vegetables and spices, to improve flavor and soften textures. The Malay community has unique cooking techniques that showcase their rich culinary traditions. For example, *Alternanthera sessilis* (L.) DC. (*karomak*) and *D. esculentum* are cooked into rendang, a traditional dish made with coconut milk and a blend of spices, cooked until thickened and reduced. This dish is served during traditional ceremonies, such as *makan basamo* (communal eating) held in the *rumah gadang* (traditional house), which occurs annually on the second day of Eid al-Fitr. This method of processing is similar to that of the Minangkabau community, which has the knowledge to process leaves from 40 plant species into a traditional dish called *rondang daun* (Agesti et al. 2023).

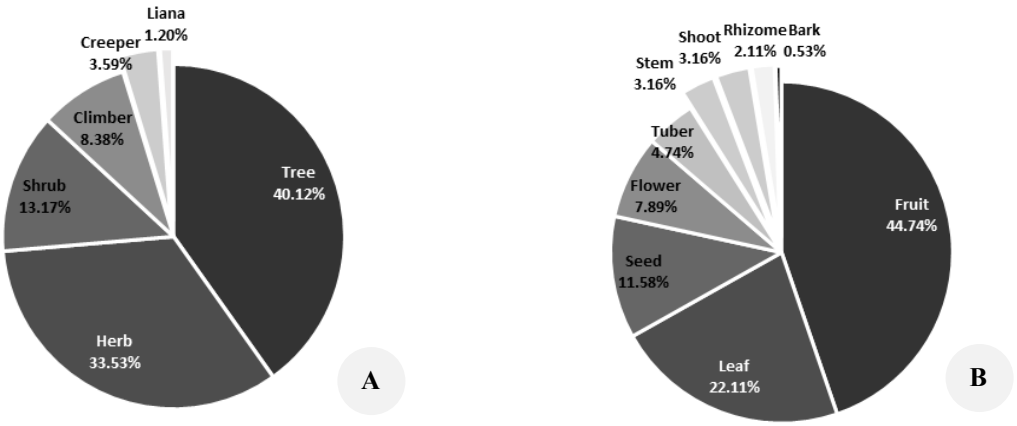

Figure 4. The percentage of growth habit (A) and Parts used of plant species used by the Malay community (B) in Kuantan Singingi District, Riau, Indonesia

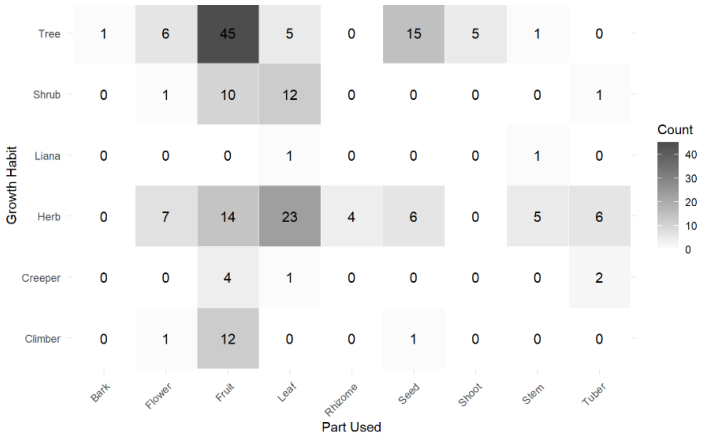

Figure 5. Heatmap of growth habit and parts used of plant species used by the Malay community in Kuantan Singingi District, Riau, Indonesia

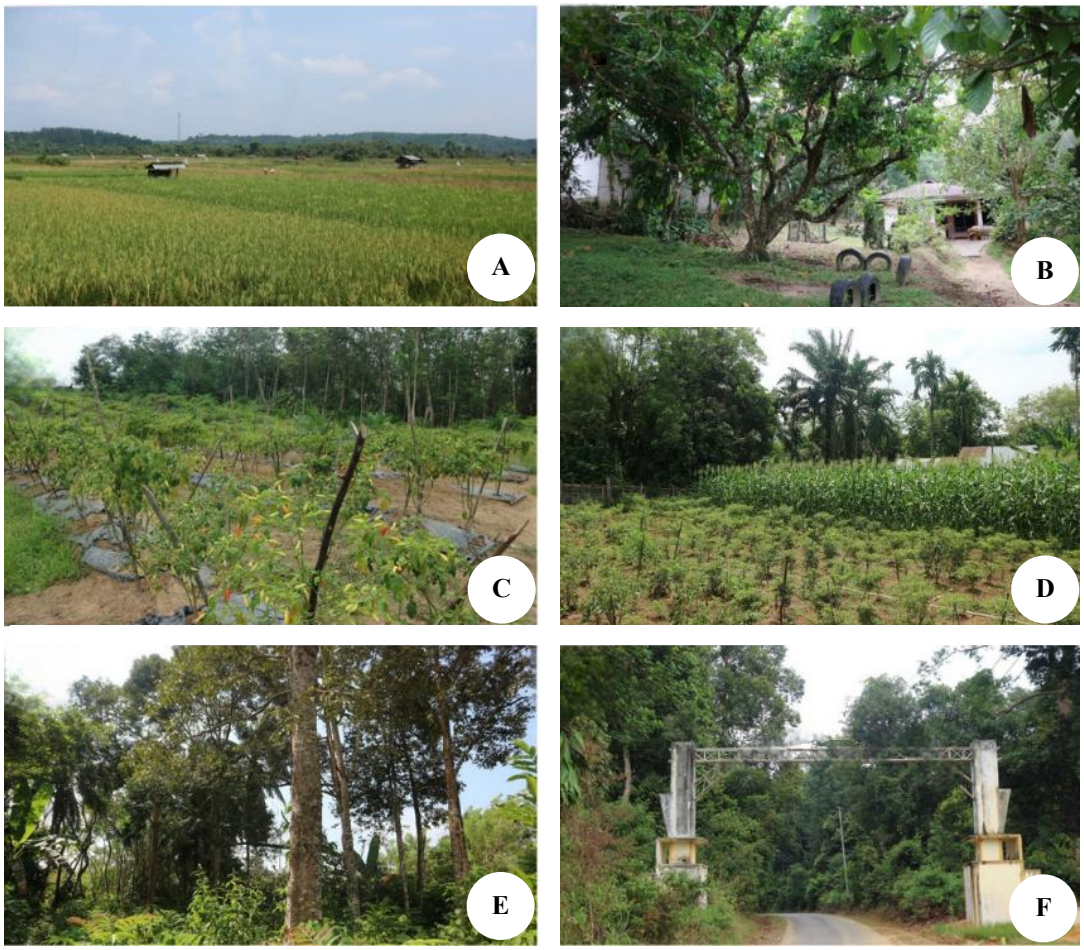

Figure 6. Landscape types of the Malay community in Kuanta Singingi District, Riau, Indonesia. A. Rice field, B. Yard, C. Agroforestry, D. Polak, E. Garden, F. Forest

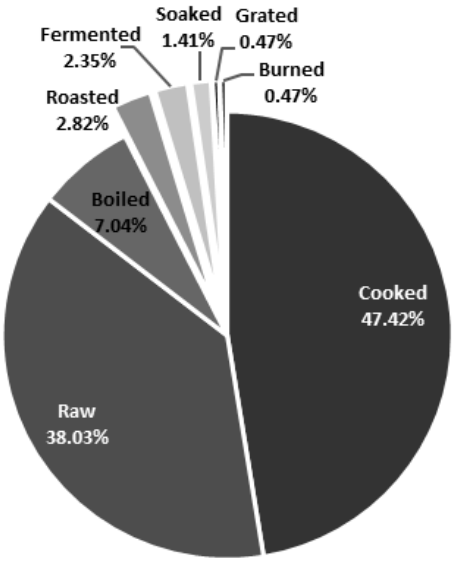

Figure 7. The percentage of preparation methods of plant species used by the Malay community in Kuantan Singingi District, Riau, Indonesia

Raw consumption in the Malay community is predominantly associated with fruits and vegetables. Fruits are often eaten fresh due to their palatable taste when ripe. In addition, vegetable plants are consumed raw by the Malay community as *ulam*. The most commonly used plant parts as *ulam* are leaves of *Anacardium occidentale* L. (*jambu monyet*), *Citrus medica* L. (*limau mentimun*), *Centella asiatica* (L.) Urb. (*pegago*), and *Melicope ptelefolia* (Champ. ex Benth.) T.G.Hartley (*tenggek burung*).

Boiling is a preferred method for snacks and vegetables to soften the texture and eliminate the bitter taste. Most snacks derived from tuberous plants require boiling before consumption, such as *D. hispida, Colocasia esculenta* (L.) Schott (*sipikul*), *Ipomoea batatas* (L.) Lam. (*ubi jala*), *Manihot esculenta* Crantz (*ubi kayu*), *Solanum tuberosum* L. (*kentang*), and *Xanthosoma sagittifolium* (L.) Schott (*taleh hitam*). Meanwhile, some snacks are roasted before consumption, such as *Castanopsis argentea* (Blume) A.DC. (*berangan*) and *Castanopsis megacarpa* Gamble (*karuntang*). The seeds of both species are traditionally dry-roasted using sand, which can distribute heat evenly and cook the seeds thoroughly.

Soaking is a preferred method to eliminate toxic compounds of plants, such as *D. hispida* and *P. edule*. Tuber of *D. hispida* possesses high levels of cyanogenic glycosides, making them toxic and unsafe for direct consumption (Widiyanti and Kumoro 2017). The Malay community in Kuantan Singingi District possesses traditional knowledge, which involves soaking tubers in running river water for 5-7 days. In contrast, the Bentong community in South Sulawesi uses a different detoxification method for this species, which involves burying the tubers in the ground for seven days to eliminate the toxins (Amboupe et al. 2019). Similarly, *P. edule* must be processed, as it contains high levels of cyanogenic compounds, rendering it toxic and unsafe for direct consumption (Sailah et al. 2021). The Malay community possesses traditional knowledge to detoxify the seeds by splitting them, extracting the endosperm, and soaking it in water for 7-10 days.

Fermenting reflects the local wisdom of the Malay community in utilizing non-cultivated plants from their surrounding environment. This method serves as a means of preserving food for long-term storage to ensure food availability over time. The young shoots of *B. vulgaris* are typically fermented traditionally into *cangkuak*, a preparation of fermented beef meat and bones using *B. vulgaris* shoots. Maslami et al. (2024) reported that *cangkuak* contains lactic acid bacteria from the genus *Lactobacillus*, which have been shown to inhibit the growth of *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella* sp., indicating its potential as a natural antibacterial agent. In addition, the seeds of *P. edule*, after detoxification, are also used as natural meat preservatives. Mirdhayati et al. (2024) demonstrated that fermentation using *P. edule* can preserve meat without reducing its nutritional value.

Local importance of food plants

Cultivated species have higher UV values than non-cultivated species because they are used more frequently. Cultivated species with the highest UV score is *C. nucifera* (Table 4). This plant is widely used in various categories such as spices, vegetables, fruits, and beverages, demonstrating its multifunctionality. Additionally, nearly all parts of this species can be utilized. The leaves serve as food wrappers. The young fruit is used as a natural refreshing beverage, while the mature fruit functions as a spice and is a key ingredient in traditional Malay snacks and drinks. The young stems (*umbuik*) are used as vegetables, and even the male flowers are harvested to produce nira water, which can be drunk fresh or further processed into sugar.

Meanwhile, the non-cultivated species with the highest UV score is *A. bilimbi* (Table 4). This species has a wide range of uses as a fruit, spice, and vegetable. The Malay community often uses it in *gulai ikan* (fish curry) dishes as a spice to give a sour taste and to reduce the fishy odor in the dish. In fact, people often refer to this plant as *belimbing gulai* because it is commonly used in *gulai* dishes. This utilization is unique because the Malay community in other parts of Riau does not commonly use it.

A high RFC value indicates that a species is known by all respondents, reflecting the successful transmission of traditional knowledge in the community (Tounekti et al. 2019). There are 17 cultivated plant species known by all respondents, with an RFC value of 1.00 (Table 4). In general, cultivated plants with high RFC values are widely grown in yards and commonly consumed. These species include *A. heterophyllus*, *C. papaya*, *C. nucifera*, *Curcuma longa* (*kunik*), *Mangifera indica* (*mangga*), *M. esculenta*, *Musa* x *paradisiaca*, and *Nephelium lappaceum* (*rambutan*).

Among the non-cultivated plants, only five species have a high RFC values of 1.00 (Table 4), including *Lansium domesticum* Corrêa (*duku*), *B. vulgaris*, *P. speciosa*, *A. jiringa*, and *D. esculentum*. These plants grow naturally in the surrounding environment, making them more familiar than non-cultivated species that are difficult to find. This study shows that plant species that are rarely used tend to be unknown to the community. These findings emphasize the importance of passing on traditional knowledge through sustainable utilization practices in daily lives.

Cocos nucifera has the highest ICS score for cultivated species (Table 4). This species has a wide range of uses, a high frequency of utilization, and a strong cultural preference. *Cocos nucifera* is mainly used as a spice for daily cooking and has become an integral part of the culinary and cultural identity of the Malay community. For instance, *galamai* (a sweet, sticky snack made from glutinous rice flour, coconut milk, and palm sugar) and *lomang* (glutinous rice and coconut milk cooked in bamboo over an open fire). These two dishes are commonly served during Eid celebrations (an Islamic celebration) and used as souvenirs when visiting family homes. In addition, *C. nucifera* is also used in the Malay Kuantan Singingi dish *konji anak loba* (porridge shaped like a bee larva, served with coconut milk), which is served during community gatherings (*gotong royong*) as a symbol of togetherness. This study is similar to research conducted by Suwardi et al. (2025), which showed that *C. nucifera* is used as an ingredient in ritual offerings, symbolizes cultural identity, and serves as an expression of gratitude to ancestral spirits in the Malay community in Sintang, West Kalimantan.

The high category ICS score was recorded for two species of non-cultivated plants, *B. vulgaris* and *Arenga pinnata* (Wurmb) Merr. (Table 4). *Bambusa vulgaris* has the highest ICS score because it plays an important role in traditional Malay cuisine in Kuantan Singingi. The shoots of this plant are popular as a vegetable during wedding ceremonies (*baralek)* and the main ingredient in a traditional fermented food (*cangkuak).* In addition, the stems of *B. vulgaris* are used as containers for making traditional snacks (*lomang)*, which are made every year during the Eid al-Fitr celebrations. Another non-cultivated species with the high ICS score is *A. pinnata*. This plant has various uses, including as a source of fruit, a beverage, a natural sweetener, and a building material. The Malay community processes the flowers of this species into *gulo onau* (palm sugar), which is used in various traditional Malay snacks, such as *konji anak loba* and *galamai*.

Table 4. High RFC, UV, and ICS categories in cultivated and non-cultivated plants used by the Malay community in Kuantan Singingi District, Riau, Indonesia

Scientific name	Family	Local name	Parts used	Use category	Ethnobotanical indices			
					FC	RFC	UV	ICS
Cultivated plants								
Artocarpus heterophyllus Lam.	Moraceae	*Cubodak*	Fruit	Fruits, vegetables	107	1.00	1.98	-
Capsicum annuum L.	Solanaceae	*Lado merah*	Fruit	Spices	107	1.00	-	-
Carica papaya L.	Caricaceae	*Katelo*	Fruit, leaf, flower	Fruits, vegetables	107	1.00	1.93	-
Cocos nucifera L.	Arecaceae	*Karambial*	Fruit, shoot, flower	Fruits, beverages, vegetables, spices	107	1.00	4.08	137.20
Curcuma longa L.	Zingiberaceae	*Kunik*	Rhizome, leaf, flower	Spices, vegetables	107	1.00	1.61	98.60
Dimocarpus longan Lour.	Sapindaceae	*Lengkeng*	Fruit	Fruits	107	1.00	-	-
Durio zibethinus L.	Malvaceae	*Durian*	Fruit, seed, flower	Fruits, vegetables	107	1.00	1.54	-
Garcinia mangostana L.	Clusiaceae	*Manggi*	Fruit	Fruits	107	1.00	-	-
Manihot esculenta Crantz	Euphorbiaceae	*Ubi kayu*	Tuber, leaf	Vegetables, snacks	107	1.00	2.01	57.60
Mangifera indica L.	Anacardiaceae	*Mangga*	Fruit	Fruits	107	1.00	-	-
Musa x *paradisiaca* L.	Musaceae	*Pisang hibrid*	Fruit, flower	Fruits, vegetables	107	1.00	2.75	93.60
Musa acuminata	Musaceae	*Pisang*	Fruit, flower	Fruits, vegetables	107	1.00	2.25	81.60
Nephelium lappaceum L.	Sapindaceae	*Rambutan*	Fruit	Fruits	107	1.00	-	-
Oryza sativa L.	Poaceae	*Padi*	Seed	Staple food	107	1.00	1.06	85.80
Solanum melongena L.	Solanaceae	*Toruang*	Fruit	Vegetables	107	1.00	-	-
Vigna unguiculata (L.) Walp.	Fabaceae	*Kacang panjang*	Fruit	Vegetables	107	1.00	-	-
Zea mays L.	Poaceae	*Jagung*	Fruit, flower	Fruits, vegetables, snacks	107	1.00	2.44	-
Non-cultivated plants								
Archidendron jiringa (Jack) I.C.Nielsen	Fabaceae	*Joriang*	Seed	Vegetables, side dishes	107	1.00	1.04	-
Arenga pinnata (Wurmb) Merr.	Arecaceae	*Onau*	Fruit, flower	Fruits, beverages	-	-	1.41	61.20
Averrhoa bilimbi L.	Oxalidaceae	*Belimbiang boreh*	Fruit	Fruits, vegetables, spices	-	-	1.52	-
Bambusa vulgaris Schrad. ex J.C.Wendl.	Poaceae	*Buluah*	Shoot	Vegetables	107	1.00	1.09	65.60
Colocasia esculenta (L.) Schott	Araceae	*Sipikul*	Tuber, stem	Vegetables, snacks	-	-	1.41	-
Diplazium esculentum (Retz.) Sw.	Athyriaceae	*Paku*	Leaf	Vegetables	107	1.00	1.08	-
Lansium domesticum Corrêa	Meliaceae	*Duku*	Fruit	Fruits	107	1.00	-	-
Parkia speciosa Hassk.	Fabaceae	*Potai*	Seed	Vegetables, side dishes	107	1.00	1.04	-
Psidium guajava J.R.Forst. & G.Forst.	Myrtaceae	*Jambu awe*	Fruit	Fruits	-	-	1.06	-
Solanum virginianum L.	Solanaceae	*Toruang asam*	Fruit	Spices	-	-	1.35	-
Tamarindus indica L.	Fabaceae	*Asam jawa*	Fruit	Fruits, spices	-	-	1.34	-

Note: FC: Frequency of Citation, RFC: Relative Frequency of Citation, UV: Use Value, ICS: Index of Cultural Significance

Transmission of local knowledge

Knowledge about food plants in the Malay community of Kuantan Singingi is passed down orally from one generation to the next. However, this process is increasingly affected by both internal and external factors. Internal factors, including age, gender, education level, and occupation, significantly influence the number of food plant species known (Figure 8). Meanwhile, external

factors such as urbanization and modernization also affect the continuity of traditional plant knowledge.

The older generations (>55 years old) have more knowledge about food plants than the younger generation (≤25 years old) (Figure 8.A). Older generations have had more time to interact with the environment and accumulate experience, while younger generations are still learning and adapting to the local environment and culture. Previous studies have shown that age has a positive effect on the number of food plants known (Punchay et al. 2020; Saupi et al. 2020), and knowledge decreases as the older generation passes away (Agboola et al. 2015).

Women have more and richer knowledge of food plants than men (Figure 8.B). Women are more involved in activities related to food plants, such as cooking, processing, and planting plants in their surroundings. This study is similar to research conducted by Saupi et al. (2020), which indicated that most food plants are cultivated or gathered by women. Additionally, farmers possess greater knowledge about food plants (Figure 8.C) due to their increased interaction with the environment and their daily activities that involve processing and using food plants.

Malay people with an elementary school education have more knowledge than those with higher education (a Bachelor's degree) (Figure 8.D). Meanwhile, people with higher formal education generally work and live in urban areas, so their interaction with the natural environment is limited, and they are more dependent on modern food sources. A study conducted by Luo et al. (2024) also reported that people who pursue education or work outside their home regions tend to abandon traditional lifestyles and adopt modern lifestyles.

The Malay communities in rural areas that still practice traditions and rituals related to plant utilization have a higher level of knowledge about food plants. In contrast, the Malay community in urban areas has adopted a modern lifestyle and tends to abandon traditional practices. This study is similar to research conducted by Suwardi et al. (2025), which showed that the traditional knowledge of the younger generation of the Malay community in Sintang, West Kalimantan, has eroded due to reduced exposure to cultural practices, influenced by modernization and urbanization. Previous studies have also shown that as more of the younger generation adopt modern lifestyles, the transmission of local knowledge about food plants from the older generations is declining (Sutrisno et al. 2020; Blue et al. 2023).

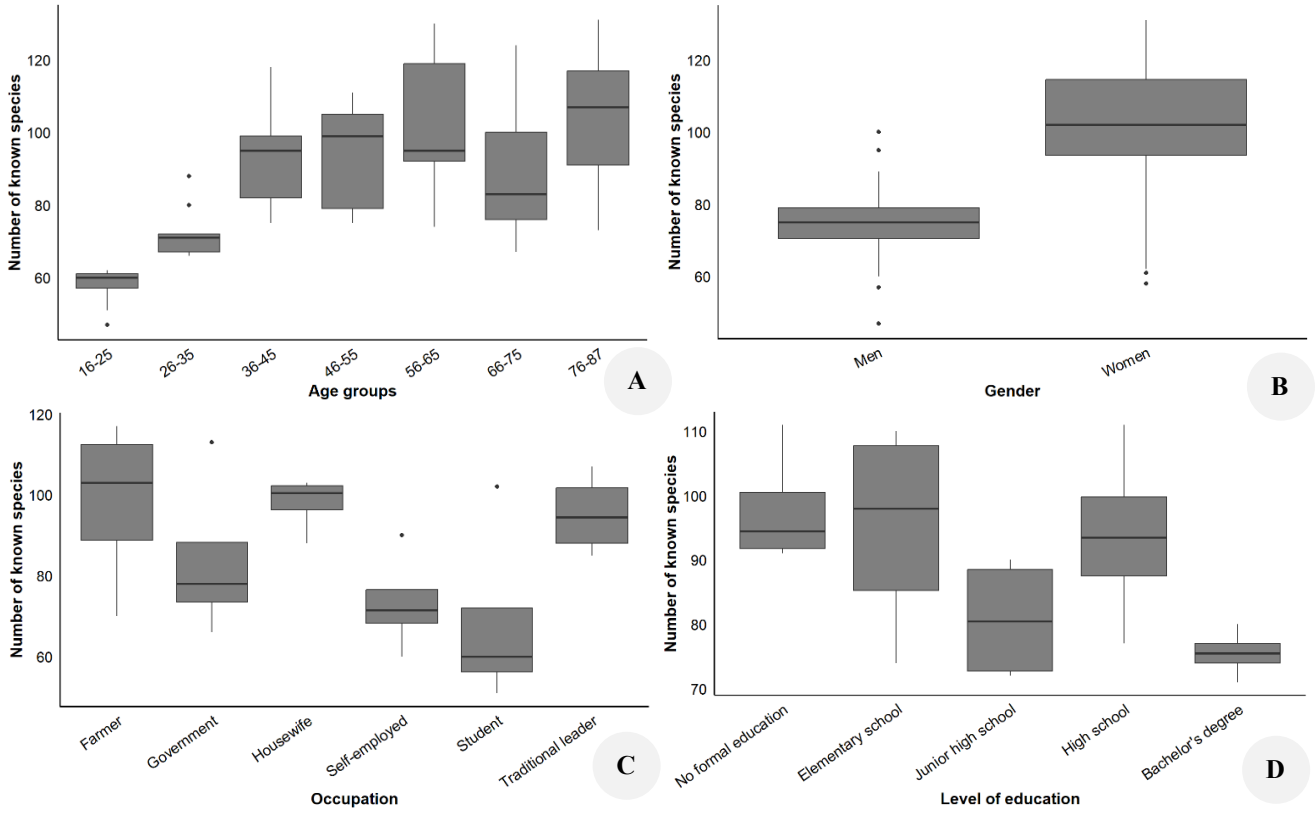

Figure 8. Food plant knowledge based on respondent characteristics. A. Age group, B. Gender, C. Occupation, D. Level of education

Table 5. Conservation strategies for non-cultivated food plants in Kuantan Singingi District, Riau, Indonesia

Conservation strategy/species	IVI value	ICS value	IVI category	ICS category
Maintaining habitat and the availability of species				
Archidendron jiringa (Jack) I.C.Nielsen (*joriang*)	93.02	28.80	Moderate	Moderate
Parkia speciosa Hassk. (*potai*)	73.87	32.00	Moderate	Moderate
Cultivating species				
Bambusa vulgaris Schrad. ex J.C.Wendl. (*buluah*)	62.48	65.60	Low	High
Arenga pinnata (Wurmb) Merr. (*onau*)	80.29	61.20	Moderate	High
Assessing and developing other potentials				
Lansium domesticum Corrêa (d*uku*)	193.31	14.40	High	Low
Cultivating, studying, and developing other potentials				
Archidendron bigeminum (L.) I.C.Nielsen (*keliling*)	8.06	5.60	Low	Low
Archidendron bubalinum (Jack) I.C.Nielsen (*kabau*)	17.72	14.40	Low	Low

Note: ICS: Index of Cultural Significance, IVI: Importance Value Index

In addition, urbanization has led to a decline in knowledge among the younger generation of the Malay community. Chikmawati et al. (2023) show that urbanization has increased the distance between residences and plant sources, resulting in limited access to non-cultivated plants. This situation has led to threats to biodiversity and local knowledge, showing signs of being forgotten and abandoned by the younger generation (Guo et al. 2022). Previous studies have also shown that local communities in Bintulu, Sarawak, Malaysia, have experienced a decline in the use of non-cultivated food plants among the younger generation, mainly due to limited access to non-cultivated plants as a result of urbanization (Saupi et al. 2020). Similarly, the Thai Song Dam community in Thailand has also experienced a decline in the use of local food plants, along with habitat loss and a shift in consumption patterns towards modern, instant food (Nguanchoo et al. 2025).

Conservation strategies of food plants

In general, our study found that knowledge about food plants among the Malay community increases with age. However, traditional knowledge is showing signs of being forgotten and abandoned by the younger generation due to environmental degradation of oil palm plantations, loss of access to food plants, and changes in modern lifestyles. The preservation of Malay traditions and customs in Kuantan Singingi must involve the younger generation to ensure the transfer of knowledge from older to younger generations. Additionally, integrating traditional knowledge about food plants into formal education—such as material on the ethnobotany of food in the *Muatan Lokal* curricula (Riau Malay culture subject) or documenting local wisdom—reduces reliance on passing knowledge down from older generations. This study also functions as a documentation effort that provides basic information on species inventory, usage patterns, processing methods, and cultural importance.

The Malay community in Kuantan Singingi District implements conservation practices based on local knowledge, one of which is through a mixed cropping system of various local rice cultivars in the same field. The community uses this strategy to reduce the risk of crop failure due to environmental changes or pest attacks. At the same time, it preserves the diversity of local varieties that have great potential as a source of germplasm. As a form of adaptation to environmental changes, the Malay community implements an agroforestry system by planting various species of food plants between young oil palms. Meanwhile, the Malay community still adheres to customary rules that prohibit tree felling in protected forest areas. Social sanctions in the form of customary ostracism have proven effective in helping to preserve the diversity of local fruit species sourced from the forest.

Conservation strategies based on the correlation between ICS and IVI (Table 5) are needed for sustainable use. Species with high or moderate ICS and IVI, such as *A. jiringa* and *P. speciosa*, should be conserved immediately through efforts to protect and maintain their natural habitats. Meanwhile, species with high ICS but low IVI, such as *B. vulgaris* and *A. pinnata,* need cultivation efforts to increase their availability. In addition, food plants with high IVI but low ICS, such as *L. domesticum*, need to explore other uses of these plants to increase their value. Plants that are considered less useful tend to be neglected and are at risk of being replaced by other species. Local species with low ICS and IVI, such as *A. bigeminum* and *A. bubalinum*, require all possible conservation strategies, including planting, exploring, and enhancing other potential values of these plants.

In conclusion, this study revealed that the Malay community in Kuantan Singingi District, Riau, Indonesia, utilizes 167 species of food plants, both cultivated and non-cultivated, obtained from six different landscape types. These plants serve various functions, including staple food, vegetables, fruits, spices, snacks, beverages, and side dishes. Key species, *C. nucifera*, has high cultural significance, as shown by its UV, RFC, and ICS values. Older generations and women play a central role in managing and passing on plant knowledge. However, erosion of knowledge among the younger generation, driven by land use change, reduced plant access, and socio-cultural shifts, poses a significant threat to biocultural heritage. Preservation of this knowledge should be supported through intergenerational transfer mechanisms, the revitalization of traditional Malay customs, and the integration of ethnobotanical education into formal curricula. The Malay community also holds valuable local

ecological knowledge that is key to biodiversity conservation. Based on the comparison of ICS and IVI values, this study recommends conservation strategies such as habitat protection for *A. jiringa* and *P. speciosa*, and cultivation-based strategies for *A. pinnata* and *B. vulgaris*. Further documentation of traditional knowledge through policy is urgently needed to support both food security and cultural identity preservation.

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Table S1. Diversity of food plants utilized by the Malay community in Kuantan Singingi District, Riau, Indonesia

Family	Scientific name	Local name	Growth habit	Cultivation status	Part used	Use category	Preparation method	Habitat
Fabaceae	*Arachis hypogaea* L.	*Kacang tanah*	Herb	Cultivated	Seed	Spices, side dishes, snacks	Cooked	Polak, Agroforestry
	Archidendron bigeminum (L.) I.C.Nielsen	*Keliling*	Tree	Non-cultivated	Seed	Vegetables, side dishes	Cooked, raw	Garden
	Archidendron jiringa (Jack) I.C.Nielsen	*Joriang*	Tree	Non-cultivated	Seed	Vegetables, side dishes	Cooked, raw	Yard, polak, garden forest, agroforestry
	Archidendron bubalinum (Jack) I.C.Nielsen	*Kabau*	Tree	Non-cultivated	Seed	Vegetables, side dishes	Cooked, raw	Garden, forest
	Clitoria ternatea L.	*Bunga telang*	Climber	Cultivated	Flower	Beverages	Boiled	Yard
	Dialium indum L.	*Keranji*	Tree	Non-cultivated	Fruit	Fruits	Raw	Forest
	Leucaena leucocephala (Lam.) de Wit	*Potai cino*	Tree	Non-cultivated	Seed	Vegetables, side dishes	Cooked, raw	Yard
	Psophocarpus tetragonolobus (L.) DC.	*Kacang belimbiang*	Climber	Cultivated	Fruit	Vegetables	Cooked	Yard, polak
	Parkia speciosa Hassk.	*Potai*	Tree	Non-cultivated	Seed	Vegetables, side dishes	Cooked, raw	Yard, polak, garden, forest
	Senna tora (L.) Roxb.	*Gelinggang*	Herb	Non-cultivated	Leaf	Vegetables	Cooked	Yard, agroforestry
	Tamarindus indica L.	*Asam jawa*	Tree	Non-cultivated	Fruit	Fruits, spices	Raw, cooked	Yard
	Vigna unguiculata (L.) Walp.	*Kacang panjang*	Climber	Cultivated	Fruit	Vegetables	Cooked	Polak, agroforestry
	Vigna radiata (L.) R.Wilczek	*Kacang hijau*	Herb	Cultivated	Seed	Snacks, vegetables	Boiled, cooked	Polak
Rutaceae	*Citrus* × *aurantium* L.	*Limau manih*	Shrub	Cultivated	Fruit	Fruits	Raw	Yard
	Citrus × *aurantiifolia* (Christm.) Swingle	*Limau kapeh*	Shrub	Cultivated	Fruit	Spices	Cooked, raw	Yard, polak
	Citrus × *aurantium f. aurantium*	*Limau peras*	Shrub	Cultivated	Fruit	Beverages	Raw	Yard, polak
	Citrus hystrix DC.	*Limau puruik*	Shrub	Cultivated	Leaf	Spices	Cooked	Yard
	Citrus × *limon* (L.) Osbeck	*Lemon*	Shrub	Cultivated	Fruit	Beverages	Raw	Yard, polak
	Citrus × *microcarpa* Bunge	*Limau kasturi*	Shrub	Cultivated	Fruit	Spices, beverages	Cooked, raw	Yard
	Citrus maxima (Burm.) Merr.	*Limau bali*	Shrub	Cultivated	Fruit	Fruits	Raw	Yard
	Citrus medica L.	*Limau mentimun*	Shrub	Non-cultivated	Leaf	Vegetables	Raw	Yard
	Melicope ptelefolia (Champ. ex Benth.) T.G.Hartley	*Tenggek burung*	Shrub	Non-cultivated	Leaf	Vegetables	Raw	Yard
Anacardiaceae	*Mangifera caesia* Jack	*Kemang*	Tree	Non-cultivated	Fruit	Fruits	Raw	Forest
	Mangifera foetida Lour.	*Ambacang*	Tree	Non-cultivated	Fruit	Fruits Spices	Raw	Yard
	Mangifera indica L.	*Mangga*	Tree	Cultivated	Fruit	Fruits	Raw	Yard, polak, agroforestry
	Mangifera laurina Blume	*Polam*	Tree	Non-cultivated	Fruit	Fruits Spices	Raw	Yard, polak, agroforestry
	Mangifera odorata Griff.	*Kuini*	Tree	Non-cultivated	Fruit	Fruits	Raw	Yard, garden

	Mangifera sumatrana Miq.	*Pauh*	Tree	Non-cultivated	Fruit	Fruits	Raw	Yard
	Anacardium occidentale L.	*Jambu monyet*	Tree	Non-cultivated	Fruit, leaf, seed	Fruits, vegetables	Raw, roasted	Yard
	Spondias dulcis Parkinson	*Kendondong*	Tree	Cultivated	Fruit	Fruits	Raw	Yard
Cucurbitaceae	*Benincasa hispida* (Thunb.) Cogn.	*Kundua*	Creeper	Cultivated	Fruit	Vegetables	Cooked	Yard, polak
	Citrullus lanatus (Thunb.) Matsum. & Nakai	*Semangka*	Creeper	Cultivated	Fruit	Fruits	Raw	Agroforestry
	Cucurbita moschata Duchesne	*Labu manih*	Creeper	Cultivated	Fruit, leaf	Snacks, vegetables	Cooked	Yard, agroforestry, polak
	Cucumis sativus L.	*Timun*	Climber	Cultivated	Fruit	Vegetables	Raw Cooked	Yard, agroforestry, polak
	Lagenaria siceraria (Molina) Standl.	*Labu aia*	Creeper	Cultivated	Fruit	Vegetables	Cooked	Yard, polak
	Luffa acutangula (L.) Roxb.	*Pitulo*	Climber	Cultivated	Fruit	Vegetables	Cooked	Yard, agroforestry, polak
	Momordica charantia L.	*Pario*	Climber	Cultivated	Fruit	Vegetables	Cooked	Yard, polak
	Momordica charantia subsp. charantia	*Pario katak*	Climber	Non-cultivated	Fruit	Vegetables	Cooked	Polak
	Sicyos edulis Jacq.	*Japan*	Climber	Cultivated	Fruit	Vegetables	Cooked	Local market
Myristicaceae	*Myristica fragrans* Houtt.	*Palo*	Tree	Cultivated	Seed	Spices	Cooked	Local market
Myrtaceae	*Psidium guajava* J.R.Forst. & G.Forst.	*Jambu awe*	Tree	Non-cultivated	Fruit	Fruits	Raw	Yard
	Rhodomyrtus tomentosa (Aiton) Hassk.	*Karamuntiang*	Shrub	Non-cultivated	Fruit	Fruits	Raw	Yard
	Syzygium aqueum (Burm.f.) Alston	*Jambu aia*	Tree	Cultivated	Fruit	Fruits	Raw	Yard, polak
	Syzygium aromaticum (L.) Merr. & L.M.Perry	*Cengkeh*	Tree	Cultivated	Flower	Spices	Cooked	Local market
	Syzygium malaccense (L.) Merr. & L.M.Perry	*Jambu jambak*	Tree	Cultivated	Fruit	Fruits	Raw	Yard, polak, garden
	Syzygium cumini (L.) Skeels	*Jambu koliang*	Tree	Non-cultivated	Fruit	Fruits	Raw	Yard
	Syzygium polyanthum (Wight) Walp.	*Salam*	Tree	Non-cultivated	Leaf	Spices	Cooked	Yard, polak
	Syzygium zeylanicum (L.) DC.	*Nasi-nasi*	Shrub	Cultivated	Leaf	Vegetables	Raw	Yard
Poaceae	*Bambusa vulgaris* Schrad. Ex J.C.Wendl.	*Buluah*	Tree	Non-cultivated	Shoot	Vegetables	Fermented, cooked	Yard, garden
	Cymbopogon citratus (DC.) Stapf	*Sorai*	Herb	Cultivated	Stem	Spices	Cooked	Yard, polak
	Dendrocalamus asper (Schult. & Schult.f.) Backer	*Botuang*	Tree	Non-cultivated	Shoot	Vegetables	Fermented, cooked	Garden
	Gigantochloa atroviolacea Widjaja	*Buluah*	Tree	Non-cultivated	Shoot	Vegetables	Fermented, cooked	Garden
	Saccharum officinarum L.	*Tobu*	Herb	Cultivated	Stem	Beverages	Raw	Yard, polak, garden
	Saccharum × edule Hassk.	*Tobu tolu*	Herb	Cultivated	Flower	Vegetables	Cooked	Yard
	Oryza sativa L.	*Padi*	Herb	Cultivated	Seed	Staple food	Cooked	Rice field
	Zea mays L.	*Jaguang*	Herb	Cultivated	Fruit, flower	Fruits, vegetables	Cooked, boiled	Polak, agroforestry
Solanaceae	*Capsicum annuum* L.	*Lado merah*	Herb	Cultivated	Fruit	Spices	Cooked	Yard, polak
	Capsicum frutescens L.	*Lado rawit*	Herb	Cultivated	Fruit	Spices	Cooked	Yard, polak, agroforestry
	Physalis angulata L.	*Lotuik-lotuik*	Herb	Non-cultivated	Fruit	Fruits	Raw	Yard, polak, agroforestry

	Solanum virginianum L.	*Toruang asam*	Herb	Non-cultivated	Fruit	Spices, vegetables	Cooked, raw	Yard, polak, agroforestry
	Solanum lycopersicum L.	*Tomat*	Herb	Cultivated	Fruit	Spices	Raw, cooked	Yard
	Solanum melongena L.	*Toruang*	Herb	Cultivated	Fruit	Vegetables	Cooked	Yard, polak, agroforestry
	Solanum torvum Sw.	*Rimbang*	Herb	Non-cultivated	Fruit	Vegetables	Raw, cooked	Yard, polak, agroforestry, garden, forest
	Solanum tuberosum L.	*Kentang*	Herb	Cultivated	Tuber	Vegetables, snacks	Boiled, cooked	Local market
Zingiberaceae	*Alpinia galanga* (L.) Willd.	*Lingkueh*	Herb	Cultivated	Rhizome	Spices	Cooked	Yard, polak
	Alpinia submutica K.Schum.	*Lome-lome*	Herb	Non-cultivated	Fruit	Fruits	Raw	Garden
	Curcuma longa L.	*Kunik*	Herb	Cultivated	Rhizome, leaf, flower	Spices, vegetables	Cooked	Yard, polak, garden
	Etlingera elatior (Jack) R.M.Sm.	*Kincung*	Herb	Non-cultivated	Flower	Spices, vegetables	Cooked	Yard, polak, garden
	Kaempferia galanga L.	*Ceku*	Herb	Cultivated	Rhizome	Spices	Cooked	Yard, polak
	Wurfbainia compacta (Sol. ex Maton) Škorničk. & A.D.Poulsen	*Sidamunggu*	Herb	Cultivated	Fruit	Spices	Cooked	Yard Polak
	Zingiber officinale Roscoe	*Sapodeh*	Herb	Cultivated	Rhizome	Spices	Cooked	Yard
Arecaceae	*Arenga pinnata* (Wurmb) Merr.	*Onau*	Tree	Non-cultivated	Fruit, flower	Fruits, beverages	Boiled	Yard, polak, garden
	Calamus sp.	*Otan*	Liana	Non-cultivated	Shoot	Vegetables	Cooked, burned	Forest
	Cocos nucifera L.	*Karambial*	Tree	Cultivated	Fruit, shoot, flower	Fruits, vegetables, spices, beverages	Raw, cooked, roasted	Yard, polak, garden
	Oncosperma tigillarium (Jack) Ridl.	*Nibung*	Tree	Non-cultivated	Shoot	Vegetables	Cooked	Forest
	Metroxylon sagu Rottb.	*Rumbio*	Tree	Non-cultivated	Stem	Snacks	Soaked, grated, cooked	Yard, forest
Phyllanthaceae	*Baccaurea motleyana* (Müll.Arg.) Müll.Arg.	*Rambai*	Tree	Non-cultivated	Fruit	Fruits	Raw	Yard, garden
	Baccaurea macrocarpa (Miq.) Müll.Arg.	*Tampui*	Tree	Non-cultivated	Fruit	Fruits	Raw	Forest
	Baccaurea polyneura Hook.f.	*Sijontiak*	Tree	Non-cultivated	Fruit	Fruits	Raw	Forest
	Baccaurea deflexa Müll.Arg.	*Tungau*	Tree	Non-cultivated	Fruit	Fruits	Raw	Forest
	Phyllanthus acidus (L.) Skeels	*Comai*	Tree	Non-cultivated	Fruit	Fruits	Raw	Yard
	Phyllanthus androgynus (L.) Chakrab. & N.P.Balakr.	*Ikuak*	Shrub	Cultivated	Leaf	Vegetables	Cooked	Yard, polak, garden, agroforestry
Sapindaceae	*Nephelium lappaceum* L.	*Rambutan*	Tree	Cultivated	Fruit	Fruits	Raw	Yard, garden, forest, polak
	Nephelium maingayi Hiern	*Pudung tunjuak*	Tree	Non-cultivated	Fruit	Fruits	Raw	Forest
	Nephelium ramboutan-ake (Labill.) Leenh.	*Pelasan*	Tree	Cultivated	Fruit	Fruits	Raw	Yard, forest
	Pometia pinnata J.R.Forst. & G.Forst.	*Matoa*	Tree	Cultivated	Fruit	Fruits	Raw	Yard, polak
	Dimocarpus longan Lour.	*Lengkeng*	Tree	Cultivated	Fruit	Fruits	Raw	Yard, polak

Amaranthaceae	*Alternanthera sessilis* (L.) DC.	*Karomak*	Herb	Non-cultivated	Leaf	Vegetables	Cooked	Agroforestry
	Amaranthus tricolor L.	*Bayam merah*	Herb	Cultivated	Leaf	Vegetables	Cooked	Polak
	Amaranthus viridis L.	*Bayam*	Herb	Cultivated	Leaf	Vegetables	Cooked	Polak, agroforestry
	Amaranthus spinosus L.	*Bayam potong*	Herb	Cultivated	Leaf	Vegetables	Cooked	Polak
Amaryllidaceae	*Allium cepa* L.	*Bawang merah*	Herb	Cultivated	Tuber	Spices	Cooked	Polak
	Allium fistulosum L.	*Daun bawang*	Herb	Cultivated	Leaf	Spices	Cooked	Yard
	Allium tuberosum Rottler ex Spreng.	*Kucai*	Herb	Cultivated	Leaf	Spices	Cooked	Yard
	Allium sativum L.	*Bawang putih*	Herb	Cultivated	Tuber	Spices	Cooked	Local market
Apiaceae	*Apium graveolens* L.	*Daun sop*	Herb	Cultivated	Leaf	Spices	Cooked	Yard
	Coriandrum sativum L.	*Ketumbar*	Herb	Cultivated	Seed	Spices	Cooked	Local market
	Foeniculum vulgare Mill.	*Adas manih*	Herb	Cultivated	Seed	Spices	Cooked	Local market
	Cuminum cyminum L.	*Jintan putih*	Herb	Cultivated	Seed	Spices	Cooked	Local market
Araceae	*Apoballis mutata* (Scort. ex Hook.f.) S.Y.Wong & P.C.Boyce	*Salimpek*	Herb	Non-cultivated	Stem	Vegetables	Cooked	Garden
	Colocasia esculenta (L.) Schott	*Sipikul*	Herb	Non-cultivated	Tuber, stem	Snacks, vegetables	Cooked, boiled	Yard, polak
	Leucocasia gigantea (Blume) Schott	*Kemumu*	Herb	Cultivated	Tuber, stem	Vegetables	Cooked, boiled	Yard, polak
	Xanthosoma sagittifolium (L.) Schott	*Taleh hitam*	Herb	Non-cultivated	Tuber	Snacks	Cooked, boiled	Yard, polak
Euphorbiaceae	*Aleurites moluccanus* (L.) Willd.	*Kemiri*	Tree	Cultivated	Seed	Spices	Cooked	Local market
	Cnidoscolus aconitifolius (Mill.) I.M.Johnst.	*Caya*	Shrub	Cultivated	Leaf	Vegetables	Cooked	Yard
	Manihot esculenta Crantz	*Ubi kayu*	Shrub	Cultivated	Tuber, leaf	Snacks, vegetables	Cooked, boiled	Yard, polak, garden, agroforestry
Meliaceae	*Sandoricum koetjape* (Burm.f.) Merr.	*Sontul*	Tree	Non-cultivated	Fruit	Fruits	Raw	Forest
	Lansium domesticum Corrêa	*Duku*	Tree	Non-cultivated	Fruit	Fruits	Raw	Yard, garden, forest
	Morus alba L.	*Bluberi*	Shrub	Non-cultivated	Fruit	Fruits	Raw	Yard
Moraceae	*Artocarpus camansi* Blanco	*Sukun*	Tree	Cultivated	Fruit	Snacks	Cooked	Yard
	Artocarpus integer (Thunb.) Merr.	*Cubodak hutan*	Tree	Non-cultivated	Fruit	Fruits	Raw	Forest, polak
	Artocarpus heterophyllus Lam.	*Cubodak*	Tree	Cultivated	Fruit	Fruits, vegetables	Raw	Yard, polak, garden, agroforestry
Clusiaceae	*Garcinia mangostana* L.	*Manggi*	Tree	Cultivated	Fruit	Fruits	Raw	Yard, garden, forest
	Garcinia xanthochymus Hook.f. ex T.Anderson	*Asam kandih*	Tree	Non-cultivated	Fruit	Spices	Cooked	Garden
	Garcinia atroviridis Griff. ex T.Anderson	*Asam galugua*	Tree	Non-cultivated	Fruit	Spices	Cooked	Local market
Lamiaceae	*Mentha × piperita* L.	*Mint*	Herb	Cultivated	Leaf	Beverages	Raw	Yard
	Ocimum basilicum L.	*Kemangi*	Herb	Cultivated	Leaf	Vegetables	Raw, cooked	Yard Polak
	Ocimum tenuiflorum L.	*Ruku-ruku*	Herb	Cultivated	Leaf	Vegetables	Cooked	Yard
Malvaceae	*Durio zibethinus* L.	*Durian*	Tree	Cultivated	Fruit, seed, flower	Fruits, spices, vegetables	Raw, cooked, fermented	Yard, polak, garden, forest
	Hibiscus sabdariffa L.	*Rosella*	Shrub	Cultivated	Leaf,	Vegetables,	Cooked, boiled	Agroforestry

					flower	beverages		
	Theobroma cacao L.	*Coklat*	Tree	Cultivated	Fruit, seed	Fruits	Raw, roasted	Yard, garden
Passifloraceae	*Passiflora quadrangularis* L.	*Balewa*	Climber	Non-cultivated	Fruit	Vegetables	Cooked	Forest
	Passiflora edulis Sims	*Markisa*	Climber	Cultivated	Fruit	Fruits	Raw	Yard
	Passiflora foetida L.	*Markisa hutan*	Climber	Non-cultivated	Fruit	Fruits	Raw	Yard, polak, agroforestry
Annonaceae	*Annona squamosa* L.	*Sarikayo*	Tree	Cultivated	Fruit	Fruits	Raw	Yard, polak
	Annona muricata L.	*Durian lauik*	Tree	Cultivated	Fruit	Fruits	Raw	Yard Polak
Asteraceae	*Cosmos pacificus* Melchert	*Kenikir*	Shrub	Cultivated	Leaf	Vegetables	Raw	Yard
	Lactuca sativa L.	*Selada*	Herb	Cultivated	Leaf	Vegetables	Raw Cooked	Yard
Brassicaceae	*Brassica oleracea* L.	*Kale*	Herb	Cultivated	Leaf	Vegetables	Cooked	Yard
	Brassica rapa L.	*Samhong*	Herb	Cultivated	Leaf	Vegetables	Cooked	Yard
Convolvulaceae	*Ipomoea aquatica* Forssk.	*Kacuke*	Herb	Cultivated	Leaf	Vegetables	Cooked	Yard, polak, rice field
	Ipomoea batatas (L.) Lam.	*Ubi jala*	Creeper	Cultivated	Tuber	Snacks	Cooked, boiled	Yard Polak
Fagaceae	*Castanopsis argentea* (Blume) A.DC.	*Berangan*	Tree	Non-cultivated	Seed	Snacks	Roasted	Forest
	Castanopsis megacarpa Gamble	*Karuntang*	Tree	Non-cultivated	Seed	Snacks	Roasted	Forest
Lauraceae	*Cinnamomum heyneanum* Nees	*Kulit manih*	Tree	Non-cultivated	Bark	Spices	Cooked	Forest
	Persea americana Mill.	*Pokat*	Tree	Cultivated	Fruit	Fruits	Raw	Yard, polak
Melastomataceae	*Melastoma malabathricum* L.	*Kaduduak*	Shrub	Non-cultivated	Fruit	Fruits	Raw	Yard, polak, garden, agroforestry, forest
	Miconia crenata (Vahl) Michelang.	*Kaduduak rimbo*	Shrub	Non-cultivated	Fruit	Fruits	Raw	Yard, polak, garden, forest
Musaceae	*Musa acuminata* Colla	*Pisang*	Herb	Cultivated	Fruit, flower	Fruits, vegetables	Raw, boiled, cooked	Yard, polak, garden, agroforestry
	Musa x *paradisiaca* L.	*Pisang*	Herb	Cultivated	Fruit, flower	Fruits Vegetables Snacks	Raw, boiled, cooked	Yard, polak, garden, agroforestry
Oxalidaceae	*Averrhoa bilimbi* L.	*Belimbiang boreh*	Tree	Non-cultivated	Fruit	Fruits, spices	Raw, cooked	Yard, polak
	Averrhoa carambola L.	*Belimbing bosi*	Tree	Cultivated	Fruit	Fruits	Raw	Yard
Piperaceae	*Peperomia pellucida* (L.) Kunth	*Sirih cina*	Herb	Non-cultivated	Leaf	Vegetables	Raw	Yard
	Piper indicum C.DC.	*Merica*	Climber	Cultivated	Seed	Spices	Cooked	Local market
Rubiaceae	*Morinda citrifolia* L.	*Mengkudu*	Tree	Non-cultivated	Fruit	Fruits	Cooked, raw	Yard, garden
	Coffea sp.	*Kopi*	Tree	Cultivated	Seed	Beverages	Roasted	Local market
Achariaceae	*Pangium edule* Reinw.	*Samauang*	Tree	Non-cultivated	Seed	Vegetables, side dishes	Fermented, soaked, cooked	Yard, garden, forest
Alismataceae	*Limnocharis flava* (L.) Buchenau	*Kalayau*	Herb	Non-cultivated	Leaf, fruit	Vegetables	Cooked	Rice field
Araliaceae	*Polyscias scutellaria* (Burm.f.) Fosberg	*Tapak leman*	Herb	Cultivated	Leaf	Spices, vegetables	Cooked	Yard, polak
Asparagaceae	*Dracaena angustifolia* (Medik.) Roxb.	*Suji*	Shrub	Cultivated	Leaf	Spices	Cooked	Yard
Blechnaceae	*Stenochlaena palustris* (Burm.f.) Bedd.	*Paku kalamidiang*	Herb	Non-cultivated	Leaf	Vegetables	Cooked	Garden
Athyriaceae	*Diplazium esculentum* (Retz.) Sw.	*Paku*	Herb	Non-cultivated	Leaf	Vegetables	Cooked	Yard, polak, garden,

								rice field
Bromeliaceae	*Ananas comosus* (L.) Merr.	*Naneh*	Herb	Cultivated	Fruit	Fruits, spices	Raw, cooked	Polak, yard
Caricaceae	*Carica papaya* L.	*Katelo*	Tree	Cultivated	Fruit, flower, leaf	Fruits, vegetables	Raw, cooked	Yard, polak, garden, agroforestry
Cactaceae	*Selenicereus monacanthus* (Lem.) D.R.Hunt	*Nago*	Climber	Cultivated	Fruit	Fruits	Raw	Yard
Dioscoreaceae	*Dioscorea hispida* Dennst.	*Gadung*	Creeper	Non-cultivated	Tuber	Snacks	Soaked, boiled	Forest
Gnetaceae	*Gnetum gnemon* L.	*Melinjo*	Tree	Cultivated	Seed, leaf	Vegetables	Cooked	Yard
Apiaceae	*Centella asiatica* (L.) Urb.	*Pegago*	Herb	Non-cultivated	Leaf	Vegetables	Raw	Yard
Menispermaceae	*Cyclea barbata* Miers	*Cincau*	Liana	Cultivated	Leaf	Beverages	Raw	Yard
Moringaceae	*Moringa oleifera* Lam.	*Kelor*	Tree	Cultivated	Leaf	Vegetables	Cooked	Yard, garden
Muntingiaceae	*Muntingia calabura* L.	*Seri*	Tree	Non-cultivated	Fruit	Fruits	Raw	Yard
Pandanaceae	*Pandanus amaryllifolius* Roxb. ex Lindl.	*Pandan*	Shrub	Cultivated	Leaf	Spices	Cooked	Yard, polak
Pontederiaceae	*Pontederia hastata* L.	*Kalayau sudu*	Herb	Non-cultivated	Leaf, flower	Vegetables	Cooked	Rice field
Sapotaceae	*Manilkara zapota* (L.) P.Royen	*Saos*	Tree	Cultivated	Fruit	Fruits	Raw	Yard, polak
Schisandraceae	*Illicium verum* Hook.f.	*Bungo lawang*	Tree	Cultivated	Flower	Spices	Cooked	Local market
Theaceae	*Camellia sinensis* (L.) Kuntze	*Teh*	Shrub	Cultivated	Leaf	Beverages	Boiled	Local market
Vitaceae	*Vitis vinifera* L.	*Anggur*	Climber	Cultivated	Fruit	Fruits	Raw	Yard

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Ecological risk assessment for sustainable tourism on Saobi Island, Indonesia

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Abstract. *Romadhon A, Rini DAS, Hilyana S. 2025. Ecological risk assessment for sustainable tourism on Saobi Island, Indonesia. Asian J Ethnobiol 8: 291-300.* The complex interplay between growing tourism and ecological sustainability is investigated in vulnerable small island ecosystems, driven by the need to protect unique biodiversity amidst anthropogenic pressures. Therefore, this research aims to conduct a systematic ecological risk assessment on Saobi Island, Indonesia, to identify specific vulnerabilities and develop evidence-based recommendations for policymakers, tourism stakeholders, and local communities to implement sustainable tourism strategies. A robust composite Ecological Risk Index (ERI) framework was used and adapted explicitly for small island environments. This methodology integrated standardized and weighted indicators across four critical ecological parameters, namely marine water quality (fecal coliform concentrations), coral reef health (coral bleaching percentages), solid waste management efficiency (beach waste density), and tourism carrying capacity (tourism density). These indicators were quantitatively combined to obtain a single numerical score representing the overall ecological risk. The assessment suggested an overall ERI value of 0.78 for Saobi Island, classifying ecological risk as "low" (in the 0.67-1.00 range). The results showed that current tourism activities were largely sustainable. However, this research identified persistent localized concerns, reporting degradation in marine water quality, ongoing anthropogenic pressures impacting coral reefs, and inadequacies in current solid waste management systems. The results also indicated the necessity for implementing integrated, resilience-focused management strategies that balanced economic, environmental, and social factors. Implications included the urgent need for optimized ecological zoning, stricter regulation of tourism activities, and consistent application of Integrated Coastal Zone Management (ICZM). The framework incorporated precise spatial planning and robust community-based monitoring for mitigating ecological risks and improving long-term environmental stewardship.

Keywords: Ecological Risk Index, environmental management, Saobi Island, small islands, sustainable tourism

Abbreviations: ERI: Ecological Risk Index, ICZM: Integrated Coastal Zone Management

INTRODUCTION

Small islands are globally recognized tourist destinations for archipelagic economies (Romadhon et al. 2020; Zhang et al. 2023), face a critical challenge: the inherent tension between generating substantial revenue and employment from tourism and preserving their fragile ecological realities (Utami et al. 2023; Zhou et al. 2023). Uncontrolled growth often leads to habitat degradation, increased waste, water pollution, and resource overexploitation, fundamentally undermining local communities and the industry (Hampton and Jeyacheya 2020; Fernandez-abila et al. 2024). This inherent tension demands scientifically informed methods to manage ecological risks and achieve sustainable tourism.

Ecological risk assessment is indispensable tool for island tourism management. This variable provides a systematic framework to synthesize complex data, translating ecological dynamics into actionable insights for identifying threats and guiding conservation (Hernández et al. 2023). Ecological Risk Index (ERI) is a widely adopted composite metric for continuous environmental risk monitoring (Zhu and Cai 2023; Li et al. 2024; Wang and Zuo 2025) ERI converts diverse ecological parameters, such as water quality, coral reef health, waste management, and tourism carrying capacity, into a single composite score (Thompson et al. 2020; Tang et al. 2022). This aggregation simplifies the communication of complex ecological conditions, making ERI powerful for small island ecosystems (Huang et al. 2022; Lu et al. 2023; Sowrav et al. 2024). Even though numerous research has explored the environmental impacts of tourism on various islands, comprehensive ERI-based evaluations for integrated risk assessment remain scarce. This is particularly evident in Indonesian archipelagic destinations, with thousands of islands increasingly reliant on tourism. Several research reports economic benefits and environmental protection, but integrated ecological risk assessments using a composite index are relatively limited in the region. This represents a critical research gap, impeding precise, evidence-based sustainable management strategies for ecologically sensitive areas.

The research gap is addressed by meticulously applying ERI framework (Ma et al. 2020; Zhang et al. 2023; Zhou et al. 2023) adapted for small island ecosystems, to Saobi Island, Indonesia. Saobi Island is renowned for the natural beauty and rich biodiversity. However, rapid tourism growth has raised concerns among stakeholders about

ecological integrity and long-term sustainability (Romadhon et al. 2020). The island's status as a conservation area since 1926, established to protect endemic bird species such as *Megapodius reinwardtii* (Dumont, 1823), shows the inherent ecological value and increased sensitivity to external pressures. The diverse marine and terrestrial ecosystems, including coral reefs, position Saobi Island as an ideal "natural laboratory" to investigate ecological risks. Tourism-environment dynamics are understood by evaluating key environmental parameters. These include marine water quality, coral reef health, and efficacy of solid waste management adopted from Romadhon et al. (2020), Hu et al. (2021), Rahmania et al. (2021), Shokri and Mohammadi (2021), Some et al. (2021), and Rahman (2024), respectively. Specifically, marine water quality and coral reef health serve as direct proxies for the impact of marine recreation and potential pollution on the highly sensitive coastal and marine ecosystems that attract tourism (Wakwella et al. 2023; Ji and Ding 2024). Solid waste management effectiveness directly reflects the capacity to handle increased anthropogenic waste from visitors, which impacts both aesthetics and ecological health (Obersteiner et al. 2021; Koiwanit and Filimonau 2023; Sakcharoen et al. 2023). Finally, tourism carrying capacity directly measures the intensity of human pressure on an ecosystem's finite resources (Utami et al. 2023; Zhang et al. 2023). The indicators were selected for the direct relevance to tourism impacts and the critical role in maintaining the island's ecosystem health and ecological integrity (Hung et al. 2021). While Saobi Island boasts diverse ecosystems including coral reefs, mangroves, coastal forests, and terrestrial wildlife habitats, the chosen indicators represent the most direct and measurable impacts related to the prevalent tourism activities and align with the adapted ERI framework's capacity for data consistency and interpretability. By integrating the concept into a comprehensive ERI, this research offers a novel method for assessing environmental pressures associated with tourism on small islands.

The overarching objective is to identify specific ecological vulnerabilities and develop evidence-based recommendations for policymakers, tourism stakeholders, and local communities in implementing sustainable tourism strategies. This research clearly states the contribution to a broader understanding of tourism for ecosystem services and community well-being in the unique, constrained context of small island environments. This integrated ecological risk analysis, with socio-economic considerations, offers an understanding critical for sustainable development (Zhang et al. 2021; Burbano et al. 2022; Nurhasanah and Van den Broeck 2022). The results serve as a crucial guide for promoting responsible tourism practices on Saobi Island, ensuring the safeguarding of invaluable ecological assets, and enhancing long-term environmental stewardship.

MATERIALS AND METHODS

Research area

This research was conducted on Saobi Island, Indonesia, an integral part of Kangean Archipelago in East Java, Indonesia. The area covered 424.83 hectares and was situated between 6°59′3.03″S-7°00′25.83″S and 115°26′45.59″E-115°28′35.25″E (Figure 1), supporting diverse terrestrial flora and fauna alongside the marine ecosystems. The vegetation consisted of coastal plants, reed communities, and herbaceous species. Dominant tree species included *Protium javanicum* Burm.fil., *Terminalia catappa* L., *Manilkara kauki* (L.) Dubard, and *Schleichera oleosa* (Lour.) Oken, contributing to ecological stability of the island. The species included the endemic *M. reinwardtii*, with *Cervus timoriensis* (de Blainville, 1822), *Macaca fascicularis* (Raffles, 1821), *Varanus salvator* (Laurenti, 1768), *Gallus varius* (Shaw, 1798), *Haliastur leucogaster*, and *Pteropus vampyrus* (Linnaeus, 1758). These species played key ecological roles, including seed dispersal and trophic regulation, emphasizing the importance of conserving biodiversity.

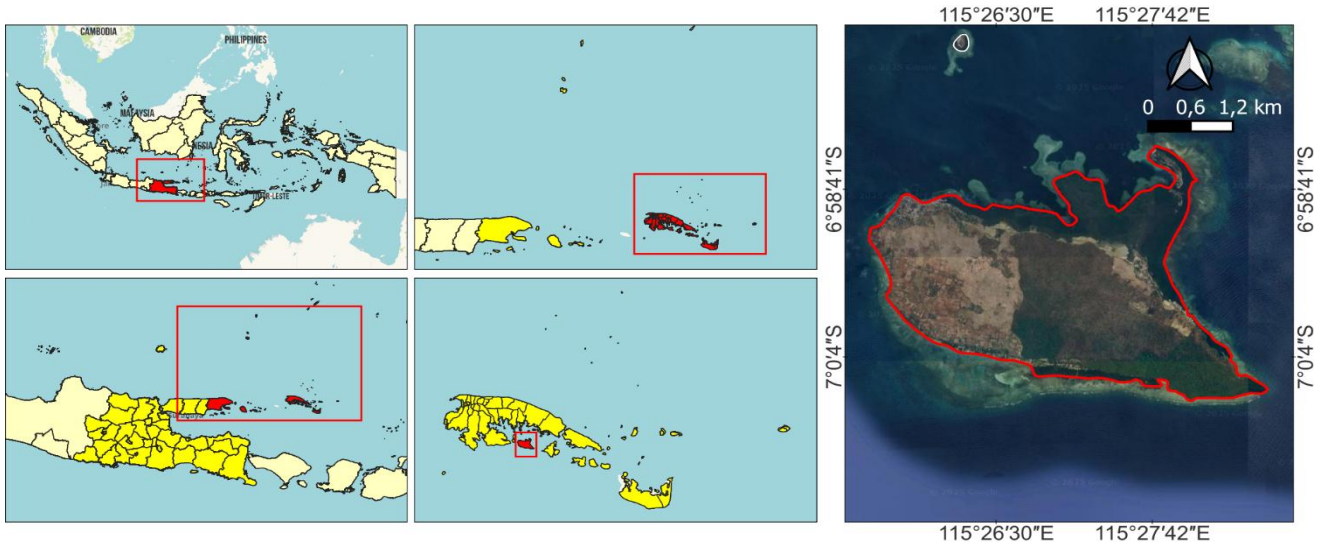

Figure 1. Location of Saobi Island in Kangean Islands, Sumenep District, East Java, Indonesia

The coexistence of multiple ecosystems, such as coral reefs, mangroves, coastal forests, and terrestrial wildlife habitats, made Saobi Island a unique natural laboratory. This ecological richness showed the uniqueness of the island as well as the vulnerability to human-induced pressures from tourism activities (Romadhon et al. 2020). Economically, the local community of Saobi Island relies heavily on tourism through various services, small businesses, and employment opportunities, a dependence that underscores the importance of balancing economic benefits with environmental preservation; the long-term sustainability of the community's well-being is intrinsically linked to the health of its natural resources. Therefore, local residents constitute a crucial stakeholder group whose active participation in and benefits from sustainable tourism practices are essential, providing an ideal environment to examine the ecological risks associated with tourism development and evaluate strategies to promote sustainable management (Hsiao et al. 2021; Yuxi et al. 2024)

Procedure

This research focused on four key environmental factors, namely water quality, coral reef condition, waste management, and tourism pressure. Data collection was carried out across two research stations, including two beaches with ten observation points, and was conducted twice to account for wet and dry seasons.

Water quality

In-situ measurements and water sampling were carried out at designated locations, referring to Some et al. (2021). Coliform bacteria concentrations were analyzed as the main indicator of environmental stress due to tourism activities. The method for detecting bacterial pollution parameters, with a particular focus on coliform bacteria, used the Plate Count.

Reef health

Based on Thompson et al. (2020), underwater visual surveys were conducted to show signs of bleaching or disease, providing a comprehensive overview of reef health.

Waste management

Data were collected by dividing each beach into 100-meter transects. Regular clean-ups were performed, and the quantity and types of waste were recorded to calculate average density (Garcés-ordóñez et al. 2020)

Potential carrying capacity

This variable directly determined tourism density by establishing the maximum sustainable number of visitors (Romadhon et al. 2020).

Data analysis

ERI system was developed to evaluate the sustainability of small island tourism. This adaptive framework incorporated measurable indicators and references specific to Saobi Island's characteristics and available data. A multi-criteria evaluation assigned each indicator a score reflecting the contribution to ecological risk. Water quality, coral reef health, waste management, and tourism pressure were selected for ecological relevance and data consistency.

Indicators were standardized using the extreme difference method to eliminate the influence of differing units and scales, ensuring consistent comparability before ERI calculation (Zhu and Cai 2023). The standardization equation was expressed as follows:

$$X'_{Ci}=(X_{Ci,\,max}-X_{Ci})/(X_{Ci,\,max}-X_{Ci,\,min})$$

Where, X'_{Ci}: Standardized score of ERI indicators (ranging from 0 to 1), X_{Ci}: Original score of ERI indicators, max X: Maximum value of the original score, min X: Minimum value of the original score

After standardization, indicator weighting was applied based on expert judgment and established guidelines (Nesticò and Maselli 2019; Shengrui et al. 2024). Indicator weightings were applied based on 15 expert judgments, which were based on a comprehensive review of relevant literature and established guidelines for ecological risk assessment. For each indicator, experts, leveraging their expertise in marine science, ecological assessment, and sustainable tourism, critically analyzed findings from previous studies on the impacts and relative significance of indicators (water quality, coral health, waste management, and potential carrying capacity) on small island ecosystems. These literature-based expert judgments allowed for the assignment of weights (water quality: 0.3, coral reef health: 0.4, waste management: 0.15, potential carrying capacity: 0.15), reflecting the importance of empirically established weights in determining ecological risk in a context similar to Saobi Island. The ERI matrix for small island as presented in Table 1. ERI was calculated by aggregating standardized and weighted indicator values to produce a single composite score, reflecting the overall ecological risk level using the formula:

$$ERI=\sum_{i=1}^{n} W_{Ci} \times X'_{Ci}$$

Where, ERI: ERI for Small Island Tourism, W_{Ci}: Weight assigned to each indicator (W1 = 0.3, W2 = 0.4, W3 = 0.15, W4 = 0.15), X'_{Ci}: Standardized score of ERI indicators (ranging from 0 to 1).

ERI provides a systematic and adaptable framework for assessing the environmental pressures associated with tourism on small islands. By integrating multiple indicators, the concept facilitates evidence-based decision-making, enabling policymakers and stakeholders to promote sustainable tourism practices. The flexibility allows adjustments based on data availability and the specific ecological conditions of each island, as a valuable tool for protecting ecosystems from the adverse impacts of tourism development. The calculated ERI values were classified into risk categories as presented in Table 2.

Table 1. ERI matrix for small island tourism

Environmental factor	Significance indicator	Quantification	Weight	Scoring	Reference
Water quality	Fecal coliform count	CFU/100 mL	0.3	1: < 276 2: 276-358 3: > 358	Some et al. (2021), Zhou et al. (2023)
Reef health	Coral bleaching	% Coral damaged	0.4	1: <25%; 2: 26-50%; 3: >50%	De et al. (2020), Thompson et al. (2020), Shokri and Mohammadi (2021), Zhu and Cai (2023)
Waste management	Beach waste density	Items/100 m²	0.15	1: < 20; 2: 20-40; 3: > 40	Garcés-ordóñez et al. (2020), Lee et al. (2021), Lukoseviciute and Panagopoulos (2021), Romadhon et al. (2024), Sempere-tortosa et al. (2024)
Potential carrying capacity	Tourism density	Number of tourists per day	0.15	1: < 100; 2: 100-200; 3: > 200	Romadhon et al. (2020), Tang et al. (2022), Li et al. (2024), Shengrui et al. (2024), Wang et al. (2024), Lu et al. (2025)

Table 2. ERI Classification

Classified risk	Index	Interpretation
Low risk	0.67-1.00	Indicates minimal ecological stress, suggesting that the island's current tourism activities exert limited negative impact on the environment and are relatively sustainable.
Moderate risk	0.33-0.66	Suggests that tourism is exerting a moderate influence on the island's natural resources and biodiversity. This level of risk requires careful management and preventive measures to avoid further degradation.
High risk	< 0.33	Reflects significant ecological stress, indicating that tourism has substantial adverse effects on the island's ecosystem and may lead to long-term environmental damage if not addressed.

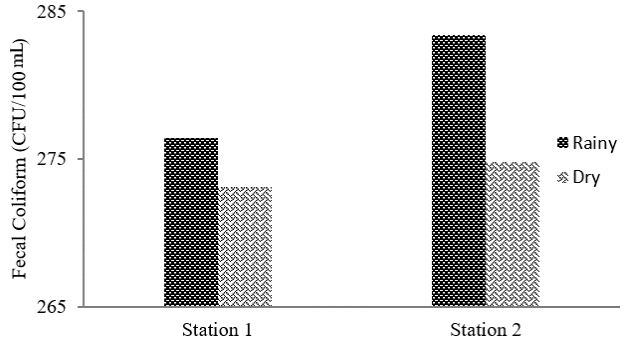

Figure 2. Mean fecal coliform count on Saobi Island by season

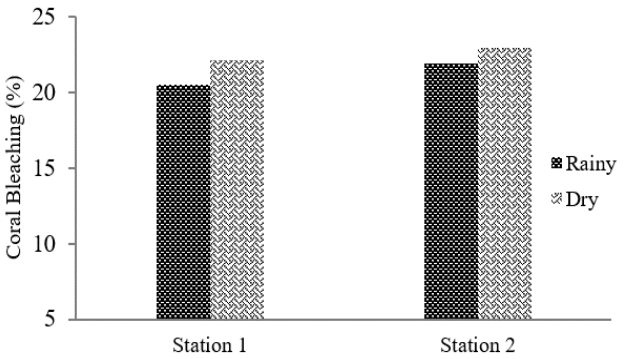

Figure 3. Observed coral bleaching percentages on Saobi Island, Indonesia

Table 3. ERI indicator score for fecal coliform count

Season	Count of fecal coliform
Rainy	281.40
Dry	273.95
Mean	277.68
X C1	2
X' C1	0.5

RESULTS AND DISCUSSION

Water quality

Water quality assessment is a critical component of ERI, focused on fecal coliform concentrations. During the rainy and dry seasons, the average fecal coliform count ranged from 279.4 to 283.4 CFU/100 mL and 273.1 to 274.8 CFU/100 mL, respectively (Figure 2).

The overall mean coliform count across all observation points was 277.68 CFU/100 mL. This value corresponded to a score of 2 in ERI framework, indicating a moderate level of ecological stress related to water quality. The standardized value for this indicator was 0.5 (Table 3)

Reef health

Coral reef health was assessed through bleaching observations, serving as a key indicator of marine ecosystem integrity. The average percentage of coral bleaching observed during the period ranged from 20% to 24% (Figure 3).

The mean coral bleaching recorded was 21.85%, which led to an indicator score of 1 in ERI framework. The standardized value for this indicator was 1 (Table 4)

Waste management

Waste management effectiveness was evaluated by quantifying solid waste accumulation on beaches. The density of solid waste on Saobi Island's beaches ranged between 35.1 and 38.2 items/100 m² (Figure 4).

The mean waste density recorded was 36.9 items/100m², which corresponded to ERI score of 2. This signified a moderate level of ecological stress, and the standardized value for this indicator was 0.5 (Table 5).

Potential carrying capacity

The potential carrying capacity of tourism density must be assessed to understand the extent of human activities and potential impacts on ecology. According to Romadhon et al. (2020), the island had a potential carrying capacity of 300 tourists per day (Figure 5), which corresponded to ERI score of 3. The standardized value for this indicator was 1 since the level of visitation did not exert excessive pressure on the natural resources (Table 6).

Ecological Risk Index (ERI)

The overall ERI for Saobi Island was calculated by integrating the standardized and weighted values of all four environmental indicators with an aggregated ERI score of 0.78 (Table 7).

Based on the classification (Table 2), ERI score of 0.78 falls in the 0.67-1.00 range, classifying Saobi Island as a "Low Risk" area. Therefore, current tourism activities are largely sustainable, exerting limited adverse impacts on the environment.

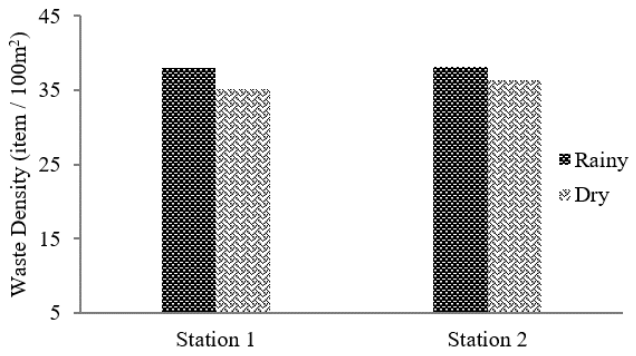

Figure 4. Beach waste density on Saobi Island, Indonesia

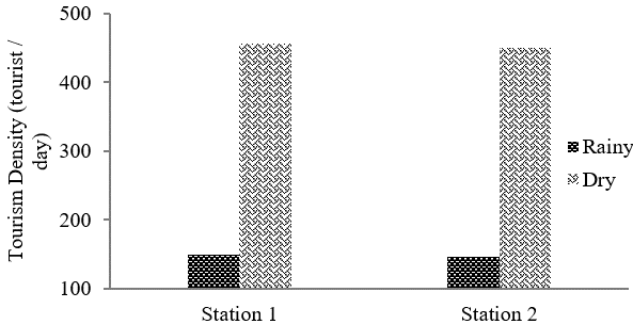

Figure 5. Tourism density on Saobi Island, Indonesia

Table 4. ERI indicator score for coral bleaching

Season	% coral affected
Rainy	21.20
Dry	22.50
Mean	21.85
X C2	1
X' C2	1

Table 5. ERI indicator score for waste density

Season	Waste density
Rainy	38.10
Dry	35.70
Mean	36.90
X C3	2
X' C3	0.5

Table 6. ERI indicator score for tourism density

Season	Tourism density
Rainy	453
Dry	147
Mean	300
X C4	3
X' C4	1

Table 7. ERI for Saobi Island, Indonesia

Environmental Component	Indicator	Weight	X' Ci	W x X' Ci
Water quality	Fecal coliform count	0.3	0.5	0.15
Reef health	Coral bleaching	0.4	1	0.4
Waste management	Beach waste density	0.15	0.5	0.08
Potential carrying capacity	Tourism density	0.15	1	0.15
Total				0.78
Classification			Low Risk	

Discussion

ERI framework applied to Saobi Island provides a comprehensive lens to examine the intricate relationship between tourism development and ecological health. The overall ERI score of 0.78, categorizing the island as "low risk," showed that ecosystem was not experiencing severe ecological stress from current tourism activities. This suggested a degree of ecological resilience since the existing management practices were relatively effective. However, a deeper, thematic analysis of individual indicators in ERI reported specific, localized vulnerabilities that necessitated proactive interventions to ensure long-term sustainability.

Water quality

On Saobi Island, the assessment of marine water quality showed a moderate level of ecological stress in ERI framework, scoring a standardized value of 0.5. The observed mean coliform count was 277.68 CFU/100 mL, corresponding to ERI indicator score of 2. Slightly higher counts were recorded during the rainy and dry seasons at an average of 281.40 CFU/100 mL and 273.95 CFU/100 mL, respectively. The elevation during the rainy season was attributed to increased surface runoff, which efficiently transported pollutants (Cabral et al. 2020). This issue was particularly pronounced in tourist-intensive areas, where existing wastewater treatment infrastructure might be insufficient to cope with seasonal runoff and the higher volume of waste generated during peak tourist periods (Utami et al. 2023; Fernandez-abila et al. 2024).

Fecal coliform observations supported the assertion that sewage was released into watersheds without adequate treatment (Verga et al. 2020). Additionally, intensive rain leads to a high input of nutrients into coastal aquatic environments, promoting the proliferation of bacteria, including coliforms (Seo et al. 2019; Aram et al. 2021). The persistent presence of coliform bacteria at moderate levels signifies potential public health hazards for visitors and residents, posing risks such as waterborne illnesses (Garcés-ordóñez et al. 2020). Moreover, coliform contamination frequently indicates broader environmental challenges, such as inadequate waste management and insufficient sanitation, which intensifies ecological risks in tourism-dependent regions (Maliga et al. 2025). The contamination severely undermines the island's reputation as a safe and pristine tourist destination, directly impacting tourism economy and recreational value (Hampton and Jeyacheya 2020). This shows an urgent need for continuous monitoring and significant enhancements in wastewater management strategies during periods of high rainfall and peak tourist activity (Yang et al. 2025).

Reef health

The observation shows a slightly higher prevalence during the dry and rainy seasons at 22.50% and 21.20% respectively. This indicates the need for a comprehensive investigation into the specific factors influencing coral reef health (Table 4). Even though elevated Sea Surface Temperatures (SST) are a primary catalyst for coral bleaching, with a 1°C increase above optimal conditions capable of inducing stress (Ardis et al. 2019), the seasonal patterns in tropical Indonesian regions are complex and do not uniformly characterize warmer dry seasons (Pathak et al. 2021). For instance, research in Karimunjawa National Park suggests that the east monsoon associated with the dry season can exhibit lower SST values than others (Ardis et al. 2019). This nuance shows that thermal stress may not fully account for the observed seasonal disparity in coral bleaching.

Since the dry season on Saobi Island is consistent with peak tourist periods, the increased incidence of coral bleaching can be attributed to the synergistic impact of intensified anthropogenic pressures on a temperature-sensitive ecosystem (Utami et al. 2023). During the periods of increased tourism, human activities substantially generate various stressors that increase coral susceptibility to bleaching (Fernandez-abila et al. 2024). These stressors include direct physical damage inflicted by marine recreational activities such as diving, snorkeling, and boating, which can harm coral structures and impede natural recovery processes (De et al. 2020). Corals physically damaged or chronically stressed by human activities exhibit reduced resilience, increasing vulnerability to environmental fluctuations (Hafezi et al. 2020). Moreover, elevated tourist numbers are frequently associated with increased waste generation and potential pollution, including untreated sewage and intensified surface runoff. The influx of contaminants decreases water quality, placing additional strain on coral ecosystems and impairing general health (Fernandez-abila et al. 2024). The underscored concerns regarding "inadequate waste management systems" and "anthropogenic pressures on coral reefs" contribute to ecological vulnerability. Therefore, the aggregated impact of intensified human-induced pressures during periods of peak tourism in the absence of seasonal thermal stress can surpass the intrinsic resilience of coral, leading to a greater frequency of bleaching during Saobi Island's dry season.

Waste management

Waste management proved to be an area requiring significant attention and presented a clear challenge for environmental sustainability. The observed beach waste density, averaging 36.9 items/m², led to a moderate ecological stress and ERI indicator scores of 0.5 and 2, respectively (Table 5). Small island areas, such as Saobi Island, exhibit complex patterns where beach waste density during the dry season can appear lower. The average beach waste density during the dry and rainy seasons was 35.70 and 38.10, respectively. This apparent paradox is driven by the dynamic interplay of waste management practices and natural environmental factors. During the dry season, intensified human activities lead to an increased generation of waste (Diaz-Farina et al. 2020; Grelaud and Ziveri 2020). However, the lower observed beach waste density is largely a direct outcome of enhanced cleanup efforts and strategic waste management, implemented to preserve the aesthetic appeal crucial for tourism industry (Battisti et al. 2020). These proactive measures aim to mitigate the immediate visual impact of waste as the overall volume rises (Andolina et al. 2021). Conversely, the rainy season often experiences

higher beach waste density despite potentially lower tourist numbers. This is primarily due to natural hydrological processes, where increased rainfall and storm events significantly amplify the transport of land-based litter and pollutants into coastal environments through surface runoff (Hitchcock 2020). The natural flushing mechanisms deposit substantial quantities of debris onto beaches, contributing to higher observed waste accumulation (Bui et al. 2021; Okuku et al. 2021). Even though tourist-generated waste undeniably increases during the dry season, effective localized management and reduced land-to-sea transport of debris contribute to the lower measured density.

The underlying increase in tourism-generated waste and associated anthropogenic pressures during the dry season continues to exert significant stress on coral reefs, contributing to bleaching events. The elevated tourist activity with potentially inadequate waste management infrastructure often leads to increased marine pollution from untreated wastewater, sewage discharge, and runoff containing various contaminants into coastal waters (Prouty et al. 2020; Rodríguez et al. 2024). This degradation of water quality, characterized by nutrient enrichment and the introduction of harmful substances, directly compromises coral health and impairs physiological functions (Donovan et al. 2020).

Marine debris poses direct threats to corals, causing physical damage, increasing susceptibility to diseases, and directly contributing to coral bleaching through abrasion, smothering, or pathogen transfer (Ying et al. 2021; Bove et al. 2023). This chronic stress from diverse tourism-related pollutants can collectively exceed the corals' intrinsic resilience, leading to an increased incidence of bleaching during the dry season.

Potential carrying capacity

The higher tourism density observed (Andolina et al. 2021) is evident from the data reported, which shows a significantly higher tourist count of 453 and 147 during the dry and rainy seasons, respectively. This increase in visitor numbers intensifies anthropogenic pressures on the fragile ecosystems and small island resources (Romadhon et al. 2020; Utami et al. 2023; Fernandez-abila et al. 2024) since excessive visitation can strain water, energy, and infrastructure. An interesting paradox is reported in the beach waste density data (Table 5) with an average of 35.70 items/m² and 38.10 items/m² during the dry and rainy seasons, respectively. This phenomenon can be attributed to more rigorous and frequent beach cleanup efforts and improved waste management strategies implemented during peak tourism to maintain the aesthetic appeal crucial for the industry (Battisti et al. 2020; Grelaud and Ziveri 2020). Conversely, the rainy season significantly amplifies the transport of land-based litter and pollutants into coastal environments through surface runoff (Yu et al. 2019; Hitchcock 2020), acting as a natural flushing mechanism (Okuku et al. 2021), thereby contributing to higher observed waste accumulation, as previously discussed in the “Waste Management” section.

The increased tourism density and associated waste generation during the dry season impact coral reef health and contribute to bleaching events, exerting considerable pressure on small island resources. The overall rise in waste generation leads to increased marine pollution, including untreated wastewater, sewage discharge, and runoff containing various contaminants into coastal waters (Prouty et al. 2020; Rodríguez et al. 2024). This degrades water quality, introduces excess nutrients, and induces stress on coral ecosystems (Donovan et al. 2020). Therefore, "inadequate waste management systems" and "anthropogenic pressures on coral reefs" contribute to ecological vulnerability. As detailed in the "Reef Health" and "Waste Management" discussions, these factors degrade water quality, introduce excess nutrients, and induce stress on coral ecosystems. Marine debris also directly impacts coral reefs by causing physical damage, increasing disease susceptibility, and directly contributing to bleaching through abrasion, smothering, or pathogen transfer (Chi et al. 2021; Ying et al. 2021; Bove et al. 2023). Physical damage from recreational activities such as diving, snorkeling, and boating increases with higher tourist numbers, harming coral structures and impeding natural recovery (De et al. 2020). Corals compromised by physical damage or chronic stress from pollution exhibit reduced resilience and are susceptible to environmental fluctuations (Hafezi et al. 2020). In this context, higher tourism density during the dry season contributes synergistically to the observed incidence of coral bleaching, surpassing the intrinsic resilience.

Management implications

The low ERI score of 0.78 for Saobi Island indicates that current environmental pressures are relatively well-managed. This shows the critical need for a proactive and integrated management approach to ensure long-term sustainability. Several integrated strategies should be prioritized to enable the long-term sustainability of Saobi Island as a tourism destination. First, continuous monitoring and management of coliform bacteria levels in water are essential, particularly in high-traffic tourist zones. Effective sewage treatment systems must be implemented to safeguard public health and maintain the reputation of the island since the systems significantly reduce faecal contamination (Aram et al. 2021; Rahmania et al. 2021). These treatments may reduce coliform levels in recreational waters by approximately 30% (Aram et al. 2021; De Giglio et al. 2022; Wakwella et al. 2023). This directly contributes to SDG 6: Clean Water and Sanitation, which aims to ensure availability and sustainable management of water and sanitation for all. Second, proactive measures to maintain coral reef health should focus on mitigating pollution, preventing destructive fishing practices, and addressing climate-related impacts. Furthermore, the promotion of responsible diving and snorkeling practices is equally critical. Evidence shows that coral reefs in marine protected areas tend to exhibit better ecological conditions (Romadhon et al. 2020, 2024). These measures can improve coral reef health by 20-50% over several years when consistently implemented (Hammerton 2018; Ardis et al. 2019; De et al. 2020). Adaptive management and continuous monitoring remain crucial to optimizing the outcomes (Thompson et al. 2020). Adaptive management and continuous monitoring remain crucial to optimizing these outcomes, contributing directly to SDG 14: Life Below Water, which aims to conserve and sustainably use the oceans, seas, and marine resources for

sustainable development. Third, improved waste management practices are required to preserve aesthetic appeal and reduce coastal litter, supporting SDG 11: Sustainable Cities and Communities (which advocates for making cities and human settlements inclusive, safe, resilient, and sustainable) and SDG 12: Responsible Consumption and Production (which promotes sustainable consumption and production patterns). Integrated programs should include recycling, sustainable waste disposal, community-based clean-up initiatives, composting, and environmental awareness campaigns.

The appearance of Saobi Island can be significantly improved through reduced litter and the safeguarding of the environment through sustainable recycling and waste management initiatives, supported by enhanced public awareness and education programs. A reasonable assessment suggests that effective waste management strategies enhance the appearance of the island by 30% to 60% (Fuldauer et al. 2019; Mestanza et al. 2019; Wang et al. 2021; Rahmania et al. 2021). In addition, zoning regulations, promoting off-season tourism, and diversifying activities regulate visitor numbers. These solutions may provide outcomes ranging from 30% to 60%, alleviating resource strain (Torres-delgado et al. 2023; Zhang et al. 2023; Zhou et al. 2023). In tourist-dependent regions, elevated tourism levels may alter ERI by increasing waste and pollution, exerting additional pressure on natural resources (Long et al. 2022; Tang et al. 2022; Ćulibrk et al. 2025). These impacts deteriorate the environment by damaging ecosystems, reducing air and water quality, and increasing habitat destruction (Long et al. 2022; Lin et al. 2024). Social, environmental, and economic considerations must be integrated in developing ecotourism programs. This method ensures local community participation in monitoring and managing sustainable tourism initiatives. The quality of the workforce and the development of supporting infrastructure play crucial roles. By combining the strategies, ecological risk factors can be effectively mitigated. Therefore, a multidimensional perspective is necessary for balancing economic, environmental, and social factors to guarantee sustainable tourism and the long-term ecological resilience of small islands as tourist destinations.

A broader perspective is required when considering the implications of island tourism for environmental sustainability. This includes evaluating the unique conditions of each island, engaging with local communities, and balancing policies with broader frameworks such as ICZM. Ecological Risk Assessment shows the importance of Ecological Function Zoning since small islands facilitate efficient spatial planning (Zhou et al. 2023). Zoning is a fundamental component of coastal management, optimizing land use and sensitive ecosystems. Community-based monitoring has proven highly effective when residents directly participate in conservation efforts, reinforcing the emphasis of ICZM on stakeholder inclusion (Chi et al. 2020; Van Cong 2020).

ICZM is a holistic strategy for managing coastal resources to balance competing stakeholder interests and safeguard fragile ecosystems (Pathak et al. 2021). This method requires integrated planning that considers all interrelated components of the coastal zone, including tourism's impacts on water quality (Dreizis 2020; Shengrui et al. 2024). Furthermore, stakeholder inclusion promotes collective responsibility and ensures that management decisions are adaptive and participatory. Adaptive management allows continuous monitoring and modification of plans in response to new data and changing circumstances (Pathak et al. 2021). In practice, small islands such as Pulo Aceh, Seribu, Karimunjawa, and Wakatobi show that waste management is significantly improved through ICZM frameworks by integrating strategies for the reduction, recycling, and proper disposal (Rahmania et al. 2021). For Saobi Island, the adaptation of ICZM minimizes the negative environmental impacts of tourism and promotes the long-term conservation of natural resources. For Saobi Island, the adaptation of ICZM minimizes the negative environmental impacts of tourism and promotes the long-term conservation of natural resources, contributing to SDG 13: Climate Action (which calls for urgent action to combat climate change and its impacts) and broader environmental stewardship.

In conclusion, despite its current classification as a low-risk area with an ERI value of 0.78, the long-term sustainability of Saobi Island necessitates a proactive and integrated management approach, especially given that water quality, coral health, waste management, and tourism density individually show varying degrees of pressure, with localized concerns and seasonal exceedances of carrying capacity signaling the need for targeted interventions. In this context, future strategies must emphasize an Integrated Coastal Zone Management framework that prioritizes robust wastewater management improvements, dedicated coral reef conservation efforts, and comprehensive waste reduction measures, which are crucial for safeguarding the natural environment and ensuring continued attractiveness for responsible tourism development. To further enhance the understanding and management of ecological risks in small island tourism, future research should integrate socio-economic indicators into the ERI framework to provide a more holistic assessment of sustainability; this can be complemented by the application of remote sensing technologies, enabling more frequent and broader spatial monitoring of key environmental parameters, and by establishing longer time-series monitoring programs for all indicators, which would allow for the detection of subtle trends, seasonal variations, and the effectiveness of implemented management strategies over extended periods, thus providing invaluable data for adaptive management and policy refinement.

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Medicinal plants for gastrointestinal ailments among the Toraja people, South Sulawesi, Indonesia

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Abstract. *Mangalik ES, Susandarini R. 2025. Medicinal plants for gastrointestinal ailments among the Toraja people, South Sulawesi, Indonesia. Asian J Ethnobiol 8: 301-311.* South Sulawesi, a province in Indonesia, is facing a significant health challenge with high rates of gastrointestinal disorders, potentially leading to fatal outbreaks. The Toraja people, a community in South Sulawesi, have a long-standing tradition of using medicinal plants to address various health issues, including gastrointestinal disorders. This study aims to document their local resources and preserve their traditional knowledge. Data were collected from October 2024 to January 2025 through semi-structured interviews with 42 informants, comprising 23 males (54.76%) and 19 females (45.24%), using snowball and purposive sampling methods. Plant specimens were collected during field exploration for the subsequent process of herbarium preparation and identification. Qualitative and quantitative data analysis methods were performed, including Use Value (UV), Fidelity Level (FL), and Informant Consensus Factor (ICF). The study identified 53 medicinal plant species from 43 genera and 29 families, with Zingiberaceae, Asteraceae, Amaranthaceae and Euphorbiaceae being the most common families. These plants are traditionally used to treat gastrointestinal issues, including diarrhea, abdominal pain, appendicitis, acid reflux, and gastritis. Herbs comprised 55% of the species, with leaves (46%) being the most used plant part, and boiling was the primary processing method. *Ageratum conyzoides* had the highest UV (0.83). The highest FL (100%) was found in *Acorus calamus, Corchorus capsularis,* and *Psidium guajava* for treatment of abdominal pain, while *Amaranthus spinosus* and *Boehmeria nivea* were reported for curing appendicitis. The highest ICF values were observed for abdominal pain with *P. guajava*, having an ICF of 0.75, and gastritis was treated with *A. conyzoides*, with an ICF value of 0.66. This study represents the first systematic ethnobotanical investigation of medicinal plants used by the Toraja community to treat gastrointestinal ailments, highlighting their diversity and contributing to the preservation of traditional knowledge, supporting species conservation, and offering potential pathways for pharmaceutical development.

Keywords: Ethnobotany, gastrointestinal ailments, indigenous knowledge, medicinal plants, Toraja

INTRODUCTION

Medicinal plants play a crucial role in global healthcare. In 2023, the World Health Organization (WHO) and the Global Traditional Medicine Centre (GTMC) reported that about 80% of people, especially in rural areas of developing countries, rely on medicinal plants due to limited healthcare access. Despite advances in modern medicine, traditional remedies remain widely used because of accessibility, ease of use, and economic benefits (Zhou et al. 2023). Many plant species with medicinal potential remain scientifically unexplored and under-documented (Horackova et al. 2023), highlighting the need for ongoing ethnobotanical studies. Indonesia, one of the world's biodiversity hotspots, has a long history of using medicinal plants. The Toraja people of South Sulawesi, Indonesia, known for their cultural identity and close connection to nature, use local flora in healing practices. However, despite their rich heritage, the Toraja remain underrepresented in ethnobotanical research, particularly regarding gastrointestinal (GI) ailments. GI conditions are the most prevalent health issues addressed with traditional remedies in this community. According to the Basic Health Survey (Ministry of Health, Basic Health Research 2013), South Sulawesi is among the five provinces with the highest incidence of GI disorders, especially diarrhea. In 2016, the Ministry of Health notes diarrhea remains endemic in Indonesia, with 18 outbreaks reported across 11 provinces in 2015, causing 1,213 cases and 30 deaths with a Case Fatality Rate (CFR) of 2.47% (Isnawati et al. 2019).

Globally, various ethnobotanical studies have shown that gastrointestinal ailments are among the most frequently treated conditions using medicinal plants in traditional societies. For instance, Ralte et al. (2024) in Mizoram, India, found that gastrointestinal ailments accounted for the highest number of medicinal plant species used, totaling 67 species (54%), with diarrhea being the most frequently treated condition. Similarly, Hani et al. (2022) reported that 142 plant species were used to treat gastrointestinal ailments in Lebanon, while Lu et al. (2022) identified 101 species used for the same purpose in Guangxi, China. In Indonesia, several ethnobotanical studies have also reported extensive use of medicinal plants to address gastrointestinal problems among local communities. Yusro et al. (2021) documented the use of various plant species for treating gastrointestinal disorders among the Dayak Muara Tribe in West Kalimantan. Khastini et al. (2021) reported similar findings among the Baduy ethnic group in West Java, while Pitopang et al. (2024) highlighted the use of medicinal plants for gastrointestinal complaints among the Kaili Ledo Ethnic in

Central Sulawesi. To date, no published study has systematically documented the use of medicinal plants for gastrointestinal disorders among the Toraja people, indicating a significant research gap in the ethnomedicinal context of Sulawesi.

Gastrointestinal (GI) ailments affect the digestive tract, including diarrhea, ulcers, gastritis, gastroenteritis, dyspepsia, acid reflux (GERD), abdominal pain, flatulence, hemorrhoids, and constipation (Lee and Kim 2022; Jabłońska and Mrowiec 2023). In South Sulawesi, these conditions are common due to unsafe water and food contamination. The Toraja have developed unique ethnomedicinal practices closely connected to beliefs, rituals, and ecological knowledge. Some remedies involve ritual offerings or preparations by traditional healers, reflecting the cultural aspect of healing. Since this knowledge is passed down orally, it is increasingly at risk of being lost because of modernization and declining intergenerational transfer (WHO 2019). Ethnobotanical research is essential to preserving this knowledge and identifying potential compounds for modern medicine. Despite the persistence and cultural importance of traditional healing practices among the Toraja people, scientific documentation of medicinal plants used specifically for GI ailments remains limited. This gap in documentation might cause a risk of neglect on plant species used in traditional healing, particularly as modernization reshapes indigenous practices (Demie et al. 2018; Mahali et al. 2023). Documenting ethnobotanical knowledge supports biodiversity preservation, sustainable resource use, drug discovery, and integration of traditional medicine into healthcare systems (Tugume et al. 2016; Tahir et al. 2023; Muhakr et al. 2024). This study addresses this gap by quantitatively analyzing GI medicinal plants in the Toraja cultural context using Use Value (UV), Fidelity Level (FL), and Informant Consensus Factor (ICF).

This study aims to (i) document medicinal plant species used to treat gastrointestinal ailments, (ii) assess their cultural importance using quantitative indices (UV, FL, ICF), (iii) analyze the plant parts used and traditional preparation methods, and (iv) investigate how this knowledge is transmitted within the community. The findings are expected to support both the preservation of ethnomedicinal knowledge and future pharmacological research.

MATERIALS AND METHODS

Study area

This study was conducted in the highlands of Toraja, South Sulawesi, Indonesia, encompassing Tana Toraja and North Toraja Districts (Figure 1). The study area is located approximately 280-355 km northeast of Makassar, the capital city of South Sulawesi Province, at coordinates 2°40'S to 3°25'S and 119°30'E to 120°25'E and featuring a mountainous landscape with elevations ranging from 600 to 2,800 masl. Geomorphologically, Toraja is dominated by rocky-mountains, hills, valleys, forests, rivers, rice fields, and plantations, with traditional settlements that follow the contours of the mountainous terrain. The area has a humid tropical climate with high annual rainfall (1,500-3,500 mm), and fertile volcanic soils support a rich diversity of vegetation, including herbs, shrubs, epiphytes, lianas, succulents, and trees—many of which are used in traditional medicine.

The population in Tana Toraja District is approximately 257,901 (132,284 males and 125,617 females). In comparison, North Toraja District has around 261,007 inhabitants (133,005 males and 128,001 females), with the majority being of the indigenous Toraja ethnic group. The study focused on four traditional villages: Sillanan (sub-district of Gandangbatu Sillanan) and Tongkonan Karuaya (sub-district of North Sangalla) in Tana Toraja, as well as Ke'te' Kesu' (sub-district of Kesu') and Pallawa (sub-district of Sesean) in North Toraja (Figure 1). Diverse ecosystems, including agroforestry landscapes, agricultural fields, plantations, rivers, and various forest types, surround these villages. This ecological and cultural diversity supports a rich plant life that is deeply embedded in the ethnobotanical knowledge of the Toraja people, playing a vital role in local healthcare, food security, and agrarian livelihoods.

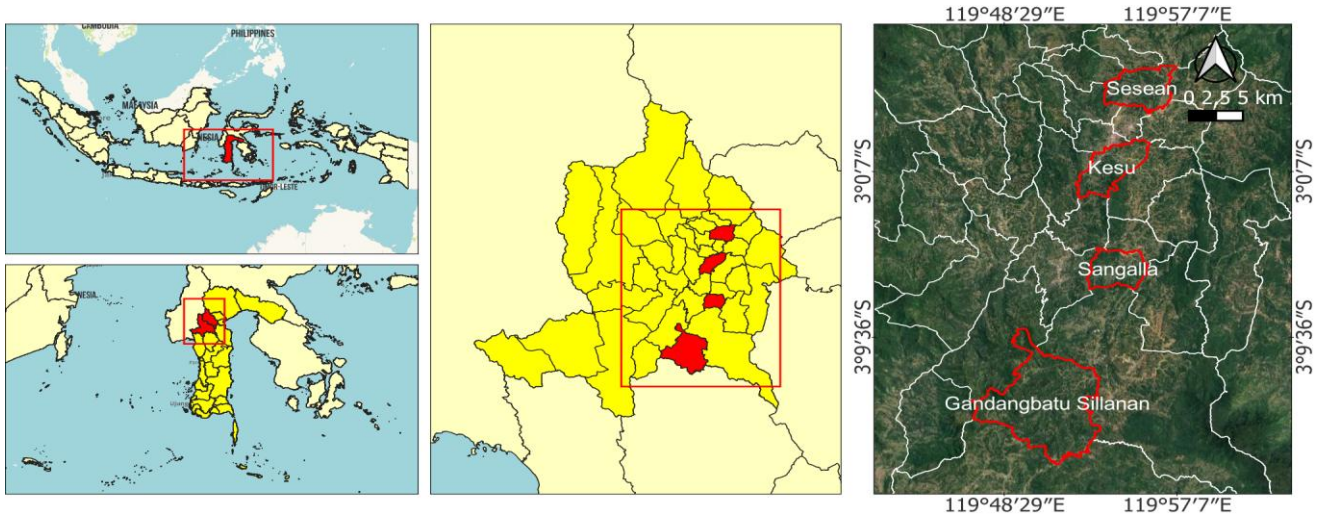

Figure 1. Map of the study area in Tana Toraja and North Toraja Districts, South Sulawesi, Indonesia

Ethnomedicinal data collection

Ethnobotanical data collection was conducted from October 2024 to January 2025 through community surveys using semi-structured interviews. A total of 42 informants were selected through purposive and snowball sampling methods across four traditional villages. These informants were chosen for their knowledge of medicinal plants and split into two groups: key informants, who were traditional healers with extensive knowledge of ethnomedicinal practices, and general informants, such as community leaders (sub-district heads, hamlet heads, customary leaders, village officials), as well as local residents with practical experience using medicinal plants. The sample size was deemed sufficient based on data saturation, where no new information emerged after several interviews (Alexiades 1996). Inclusion criteria included adults (≥18 years) with experience in using medicinal plants, while those lacking such knowledge were excluded.

The demographic profiles of the informants were diverse, covering males and females of different ages and occupations. The interviews were conducted to gather detailed ethnomedicinal data, including the types of plants used, the health conditions and ailments they addressed, plant parts used, methods of preparation and application, and strategies for preserving both traditional knowledge and plant habitats. As no new plant species or ethnomedicinal information emerged in the last three consecutive interviews, this confirms sample adequacy. GI ailments mentioned by participants were classified into biomedical categories following Lee and Kim (2022) and Jabłońska and Mrowiec (2023). The study followed ethical principles of voluntary participation and community respect. Prior informed consent was obtained verbally from all participants before interviews and plant collection, and the research followed the ethical guidelines of the International Society of Ethnobiology (ISE 2006), including principles of respect, confidentiality, and fair benefit-sharing.

Plant collection and identification

Medicinal plant specimens were collected during informant-guided field work. The plants were collected from gardens, home yards, or forests. Whole individual specimens were collected for small plants, while branches (30-40 cm) with leaves, flowers, and fruits were taken from larger trees. Reproductive organs (flowers, fruits, or seeds) of tall trees were obtained using tools. Samples were labeled, photographed, and pressed between newspaper sheets, then preserved in 70% alcohol. Detail photographs were taken for large specimens unsuitable for herbarium preparation. Collected samples were dried in an oven at 60-70°C for 2-6 days at the Plant Systematics Laboratory, Universitas Gadjah Mada (UGM), Yogyakarta, Indonesia, before being mounted on herbarium sheets for identification and storage. The identification of medicinal plant specimens was conducted using reference books such as *Tumbuhan Berguna Indonesia* (Heyne 1987), *Illustrated Guide to Tropical Plants* (Corner and Watanabe 1969), *Flora of Malesiana* (Van Steenis 1955), and the plant specimen database World of Flora Online (https://www.worldfloraonline.org/). The validity of species names and author citations was confirmed using online databases such as Plants of the World Online (https://powo.science.kew.org/). Taxonomists from the Department of Plant Systematics at UGM validated all identifications. Herbarium specimens were prepared for most species and deposited at the Faculty of Biology, UGM. Some species, particularly large trees or easily recognized taxa, were documented through photographs and field notes.

Data analysis

The data were analyzed using both qualitative-descriptive and quantitative methods. Descriptive-qualitative analysis was employed to examine the data and information related to the use of plants as traditional medicine within the community in a comprehensive and detailed manner. Meanwhile, quantitative analysis was conducted to obtain measurable and objective data regarding the complexity of medicinal plant species utilized by the community. The quantitative analysis includes the Use Value Index (UV), Fidelity Level (FL), and Informant Consensus Factor (ICF).

Use Value (UV)

UV is used to assess the relative importance of a plant species based on its frequency of use by the community. The UV is calculated using the formula:

$$UVi = \frac{\Sigma Ui}{n}$$

Where, UV represents the total use value of a medicinal plant species, U is the number of usage reports for a species, and n is the total number of informants interviewed (Phillips et al. 1994).

Fidelity Level (FL)

FL is used to determine the percentage of specific use of a plant species in treating a particular disease. The formula for FL is:

$$FL\% = \frac{Ip}{IU} \text{ x } 100$$

Where FL% is the percentage of the Fidelity Level Index of a plant species, Ip is the number of informants who report the use of the species for a particular disease, and IU is the total number of informants who report the use of the species for various diseases (Friedman 1986).

Informant Consensus Factor (ICF)

ICF is used to determine the level of agreement among informants regarding the use of plants for a specific disease category. The following formula is applied for ICF:

$$ICF = \frac{(Nur - Nt)}{(Nur - 1)}$$

Where ICF is the Informant Consensus Factor value for a specific disease category, Nur is the number of reports on the use of a plant species to treat that particular disease

category, and Nt is the total number of plant species used to treat that disease category (Heinrich 1998).

RESULTS AND DISCUSSION

Demographic profiles of the informants

The informant profile was presented based on four categories: gender, level of knowledge, age, and occupation (Table 1). Among the 42 informants, 23 were male (54.76%) and 19 were female (45.24%). The majority of informants were traditional healers (40.48%). In terms of age, most informants were 61-70 years old (28.57%), with an average age of 63 years, with the youngest being 41 and the oldest 86. Regarding occupation, the majority of informants were farmers (69.05%). The information collected included the types of plants used, the plant parts utilized, the diseases treated, the methods of use, and the types of plant conservation efforts.

Diversity of medicinal plants

In the present study, a total of 53 medicinal plant species were recorded in the treatment of gastrointestinal disorders, encompassing 43 genera and 29 families (Table 2). These species are traditionally used to treat a variety of gastrointestinal ailments, including diarrhea, abdominal pain, acid reflux (GERD), appendicitis, gastritis/gastric ulcer, stomach ulcers, flatulence, hemorrhoids, gastroenteritis, and constipation. The family of Zingiberaceae was the most frequently represented, with 8 species documented, followed by Asteraceae with 4 species, and Amaranthaceae and Euphorbiaceae, each represented by 3 species (Figure 2).

Among the 53 medicinal plant species recorded, *Ageratum conyzoides* L. had the highest Use Value (UV = 0.83), reflecting its wide usage across multiple gastrointestinal conditions, particularly gastritis and gastric ulcers. Pharmacologically, this species is known to contain flavonoids such as kaempferol, quercetin, and sinensetin, which exhibit anti-inflammatory, antibacterial, and gastroprotective activities (Aladdin et al. 2017; Rajput et al. 2022). Other highly cited species include *Psidium guajava* L. and *Acorus calamus* L., both of which showed high Fidelity Levels (FL = 100%) for treating abdominal pain. These plants have documented antidiarrheal and antispasmodic effects and are commonly available in homegardens or nearby forests, making them easily accessible for local communities. The study recorded both cultivated species, such as *Zingiber officinale* Roscoe*, Anredera cordifolia* (Ten.) Steenis*,* and *Senna alata* (L.) Roxb., as well as wild-collected species like *Hyptis capitata* Jacq.*, Flemingia strobilifera* (L.) W.T.Aiton and *Euphorbia hirta* L.. This highlights the community's reliance on both managed and natural ecosystems for traditional medicine. Although none of the recorded species are currently listed as endangered in the IUCN Red List, the potential future threats from continued harvesting from the wild, particularly for endemic or slow-growing plants, are a cause for concern. These findings underline the need for sustainable harvesting practices and conservation awareness. Representative species used for gastrointestinal ailments by the Toraja community are illustrated in Figure 3.

Table 1. Demographic profiles of the informants

Category	Description	Number of informants (n=42)	Respondent frequency (%)
Gender	Male	23	54.76
	Female	19	45.24
Level of knowledge	Traditional healers	17	40.48
	Community leader	10	23.81
	Traditional medicine users	15	35.71
Age group (years old)	40-50	8	19.05
	51-60	10	23.81
	61-70	12	28.57
	71-80	9	21.43
	>80	3	7.14
Occupation	Farmer	29	69.05
	Traditional leader	7	16.67
	Government official	4	9.52
	Housewife	2	4.76

Note: n: Total of informants

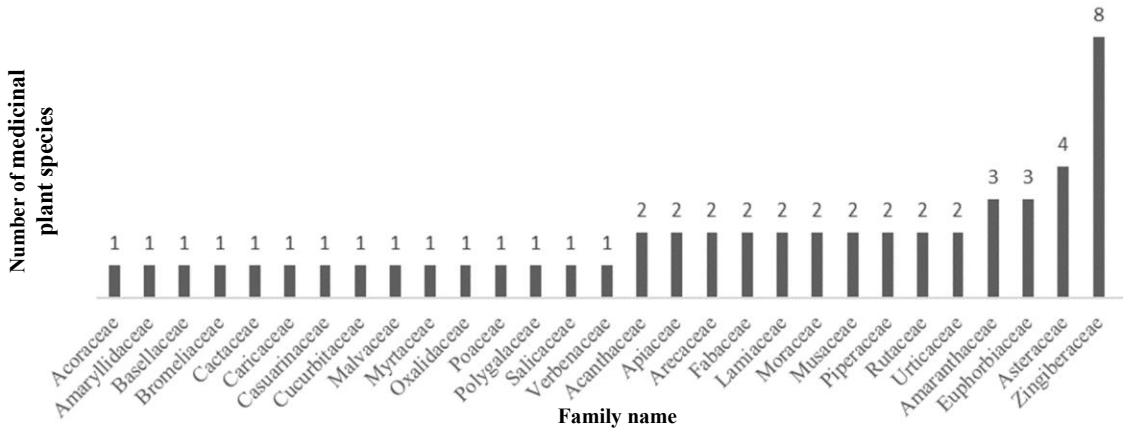

Figure 2. Family-wise medicinal plant species to treat gastrointestinal disorders by the Toraja community in South Sulawesi, Indonesia

Table 2. Medicinal plants used by the Toraja people to treat gastrointestinal ailments in South Sulawesi, Indonesia

Family	Scientific name	Vernacular name	Growth form	Parts used	Gastrointestinal ailments treated	Mode of use	UV	FL (%)
Acanthaceae	*Andrographis paniculata* (Burm.fil.) Nees	*Sambiloto*	Herb	Leaves	Abdominal pain, diarrhea	Boiling	0.26	14.29
Acanthaceae	*Graptophyllum pictum* (L.) Griff.	*Katilamun*	Shrub	Leaves	Hematemesis	Boiling	0.26	12.50
Acoraceae	*Acorus calamus* L.	*Kariango*	Herb	Rhizome	Abdominal pain	Eaten raw	0.07	100
Amaranthaceae	*Alternanthera sessilis* (L.) R.Br. ex DC.	*Parapa*	Herb	Leaves, whole plant	Acid reflux (GERD), appendicitis	Boiling	0.07	50.00
Amaranthaceae	*Alternanthera philoxeroides* (Mart.) Griseb.	*Bekke rada*	Herb	Leaves	Hernia	Boiling	0.05	100
Amaranthaceae	*Amaranthus spinosus* L.	*Bayam duri*	Herb	Leaves	Appendicitis	Boiling	0.05	100
Amaryllidaceae	*Allium cepa* var. *aggregatum* G.Don	*Lassuna rarang*	Herb	Tuber	Flatulence	Pounded	0.07	50.00
Apiaceae	*Centella asiatica* (L.) Urb.	*Leme'*	Herb	Leaves, whole plant	Abdominal pain, liver, gastritis/gastric ulcer	Boiling, crushed	0.43	8.33
Apiaceae	*Apium graveolens* L.	*Daun so'*	Herb	Leaves	Acid reflux, liver	Boiling	0.10	50.00
Arecaceae	*Cocos nucifera* L.	*Kaluku*	Tree	Fruit water	Poisoning	Drunk directly	0.10	100
Arecaceae	*Arenga pinnata* (Wurmb) Merr.	*Induk*	Tree	Fruit	Jaundice	Eaten raw	0.21	14.29
Asteraceae	*Ageratum conyzoides* L.	*Tassi'-tassi'*	Herb	Leaves, whole plant	Gastritis/gastric ulcer, abdominal pain	Crushed, boiling	0.83	54.17
Asteraceae	*Gymnanthemum amygdalinum* (Delile) Sch.Bip. ex Walp.	*Kloropil*	Shrub	Leaves	Gastritis/gastric ulcer, acid reflux	Crushed, boiling	0.64	23.53
Asteraceae	*Chromolaena odorata* (L.) R.M.King & H.Rob.	*Sarambuallo*	Shrub	Leaves	Gastritis/gastric ulcer	Crushed, boiling	0.79	38.10
Asteraceae	*Pluchea indica* (L.) Less.	*Beluntas*	Shrub	Leaves	Acid reflux (GERD)	Crushed, boiling	0.12	50.00
Basellaceae	*Anredera cordifolia* (Ten.) Steenis	*Minahong*	Climber	Leaves	Gastritis/gastric ulcer	Boiling	0.17	33.33
Bromeliaceae	*Ananas comosus* (L.) Merr.	*Pondan*	Herb	Ripe fruit	Constipation	Eaten raw	0.05	100
Cactaceae	*Leuenbergeria bleo* (Kunth) Lodé	*Daun tujuh bilah*	Shrub	Leaves	Gastritis/gastric ulcer	Boiling	0.02	100
Caricaceae	*Carica papaya* L.	*Taliki*	Tree	Leaves, fruit	Jaundice, gastritis, abdominal pain	Boiling, eaten raw	0.29	14.29
Casuarinaceae	*Casuarina junghuhniana* Miq.	*Buangin*	Tree	Root	Jaundice	Boiling	0.02	100
Cucurbitaceae	*Cucurbita moschata* (Duchesne) Duchesne ex Poir.	*Lau*	Climber	Fruit	Gastritis/gastric ulcer	Boiling	0.07	66.67
Euphorbiaceae	*Acalypha indica* L.	*Akar kucing*	Herb	Whole plant	Acid reflux (GERD)	Boiling	0.05	100
Euphorbiaceae	*Jatropha curcas* L.	*Pallan*	Shrub	Leaves	Poisoning	Boiling	0.60	6.67
Euphorbiaceae	*Euphorbia hirta* L.	*Pa'tik-pa'tik*	Herb	Whole plant	Appendicitis	Boiling	0.07	50.00
Fabaceae	*Flemingia strobilifera* (L.) W.T.Aiton	*Ora'-ora'*	Shrub	Leaves, root	Gastritis/gastric ulcer, acid reflux (GERD)	Boiling	0.05	50.00
Fabaceae	*Senna alata* (L.) Roxb.	*Galinggang*	Shrub	Leaves	Gastritis/gastric ulcer	Boiling	0.12	33.33
Lamiaceae	*Hyptis capitata* Jacq.	*Swalang*	Herb	Leaves, whole plant	Flatulence	Crushed, boiling	0.26	90.00
Lamiaceae	*Ocimum sanctum* L.	*Kamangi*	Shrub	Whole plant	Gastroenteritis	Boiling	0.07	33.33
Malvaceae	*Corchorus capsularis* L.	*Songkadulang*	Herb	Fruit, seeds	Abdominal pain, diarrhea	Pounded, eaten raw	0.12	100
Moraceae	*Artocarpus altilis* (Parkinson) Fosberg	*Baka'*	Tree	Leaves	Liver, abdominal pain	Boiling	0.19	20.00
Moraceae	*Ficus septica* Burm.fil.	*Lebannu*	Shrub	Leaves	Jaundice	Boiling	0.12	50.00

Musaceae	*Musa* spp.	*Punti*	Herb	Fruit	Gastritis/gastric ulcer	Eaten raw	0.19	28.57
Musaceae	*Musa balbisiana* Colla	*Punti sanggara*	Herb	Fruit	Gastritis/gastric ulcer	Eaten raw	0.02	100
Myrtaceae	*Psidium guajava* L.	*Dambu batu*	Tree	Leaves	Abdominal pain, diarrhea, gastroenteritis	Eaten raw, crushed	0.50	100
Oxalidaceae	*Oxalis corniculata* L.	*Pisik*	Herb	Whole plant	Gastritis/gastric ulcer	Boiling, crushed	0.21	14.29
Piperaceae	*Piper betle* L.	*Daun bolu*	Climber	Leaves	Gastritis/gastric ulcer	Crushed, boiling	0.26	16.67
Piperaceae	*Piper umbellatum* L.	*Lepo*	Shrub	Leaves	Hemorrhoids, hernia	Boiling	0.07	100
Poaceae	*Imperata cylindrica* (L.) Raeusch.	*Ria*	Herb	Root	Flatulence	Boiling	0.21	16.67
Polygalaceae	*Polygala paniculata* L.	*Akar wangi*	Herb	Root	Flatulence	Boiling, apply directly	0.05	100
Rutaceae	*Citrus ×aurantiifolia* (Christm.) Swingle	*Lemo tadi*	Shrub	Leaves	Flatulence	Crushed, Squeezed	0.14	20.00
Rutaceae	*Citrus hystrix* DC.	*Lemo dondo'*	Shrub	Fruit	Jaundice	Squeezed	0.07	50.00
Salicaceae	*Flacourtia rukam* Zoll. & Moritzi	*Karondang*	Tree	Leaves	Appendicitis	Boiling	0.05	50.00
Urticaceae	*Boehmeria nivea* (L.) Gaudich.	*Karra'-karra'*	Herb	Leaves	Appendicitis	Boiling	0.05	100
Urticaceae	*Boehmeria cylindrica* (L.) Sw.	*Sissing tuak*	Herb	Leaves	Appendicitis	Boiling	0.10	33.33
Verbenaceae	*Lantana camara* L.	*Kassi'-kassi'*	Shrub	Leaves	Gastritis/gastric ulcer	Crushed, boiling	0.40	27.27
Zingiberaceae	*Zingiber cassumunar* Roxb.	*Bangle*	Herb	Rhizome	Abdominal pain, diarrhea	Pounded, eaten raw	0.31	66.67
Zingiberaceae	*Zingiber montanum* (J.Koenig) Link ex A.Dietr.	*Bangle lotong*	Herb	Rhizome	Abdominal pain, diarrhea	Eaten raw	0.02	100
Zingiberaceae	*Zingiber officinale* Roscoe	*Laiya*	Herb	Rhizome	Flatulence, jaundice	Boiling, eaten raw	0.14	20.00
Zingiberaceae	*Zingiber officinale* var. *rubrum.*	*Laiya rarang*	Herb	Rhizome	Abdominal pain	Boiling	0.02	100
Zingiberaceae	*Curcuma longa* L.	*Kunyi'*	Herb	Rhizome	Gastritis/gastric ulcer, GERD, jaundice	Grated, eaten raw	0.17	66.67
Zingiberaceae	*Curcuma caesia* Roxb.	*Kunyi' lotong*	Herb	Rhizome	Abdominal pain	Eaten raw	0.07	100
Zingiberaceae	*Curcuma zanthorrhiza* Roxb.	*Tammula'*	Herb	Rhizome	Gastritis/gastric ulcer	Grated, pounded	0.10	25.00
Zingiberaceae	*Alpinia purpurata* (Vieill.) K.Schum.	*Likkua' rarang*	Herb	Rhizome	Gastritis/gastric ulcer	Grated	0.02	100

Note: UV: Use Value, FL: Fidelity Level

Figure 3. Medicinal plants used for gastrointestinal ailments by the Toraja community in South Sulawesi, Indonesia. A. *Ageratum conyzoides*, B. *Gymnanthemum amygdalinum*, C. *Chromolaena odorata,* D. *Hyptis capitata,* E. *Euphorbia hirta,* F. *Jatropha curcas*

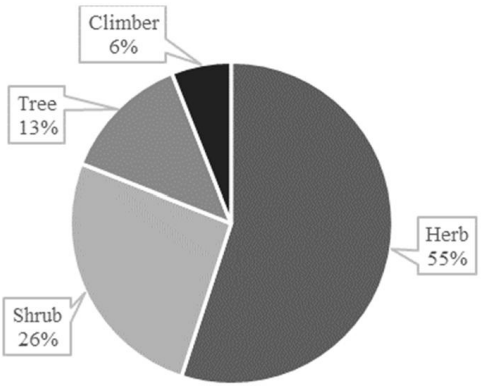

Figure 4. Growth forms of medicinal plants used by the Toraja people to treat gastrointestinal ailments in South Sulawesi, Indonesia

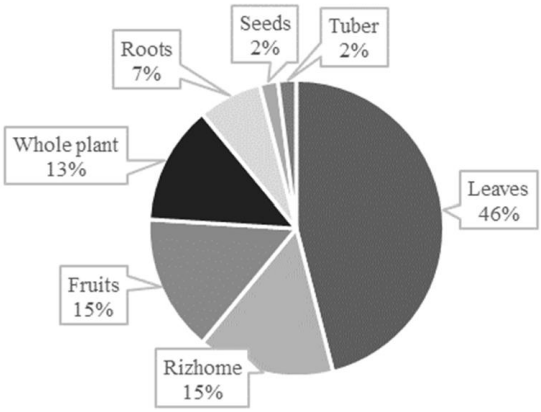

Figure 5. Plant parts used in traditional remedies to treat gastrointestinal ailments by the Toraja people in South Sulawesi, Indonesia

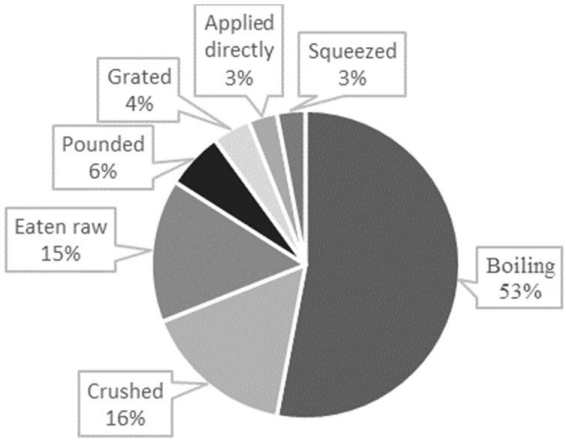

Figure 6. Modes the preparation or processing methods of traditional herbal recipes to treat gastrointestinal ailments by the Toraja people in South Sulawesi, Indonesia

Medicinal plants' growth form

The medicinal plant species documented in this study exhibited a variety of growth forms, reflecting their ecological adaptation and accessibility for traditional use. These growth forms included herbs, shrubs, trees, and climbers. Herbs constituted the highest proportion, accounting for 29 species (55%) of the total 53 species recorded, followed by shrubs with 14 species (26%), trees with 7 species (13%), and climbers with 3 species (6%). The distribution of these growth forms is illustrated in Figure 4, providing a visual representation of their relative importance of usage in the study area.

Plant parts used and mode of preparation

There was diversity in plant parts utilized for traditional remedies to treat gastrointestinal ailments by the Toraja community. Some species have multiple plant parts used, and the calculation is based on the total number of use reports rather than the total number of species. The most frequently used part was leaves, with 28 species (46%) of the total, reflecting their accessibility and ease of preparation. Other plant parts used in herbal preparations were rhizome (15%), fruits (15%), and whole plant (13%). Meanwhile, roots (7%), seeds (2%), and tubers (2%) were used less frequently. The widespread use of leaves and fruits indicates a preference for renewable and easily harvestable plant parts. The proportion of plant parts used is illustrated in Figure 5, highlighting their relative significance in traditional medicinal practices.

The modes of preparation for medicinal plant recipes varied depending on the ailment being treated and the specific part of the plant used. Some species have multiple plant parts used, and the calculation is based on the total number of use reports rather than the total number of species. Boiling was the most common method (53%), followed by crushed (16%), eaten raw (15%), pounded (6%), grated (4%), squeezed (3%), and direct application without any specific preparation (3%). These methods reflect the community's practical knowledge in extracting bioactive compounds and ensuring their efficacy. Figure 6 presents the proportional use of different preparation methods.

Gastrointestinal ailments categories and medicinal plant utilization

Local communities of Toraja employed a wide range of plant species to manage digestive problems, highlighting the depth of ethnomedicinal knowledge and the significance of traditional healthcare practices. Among the various conditions of gastrointestinal ailments, gastritis/gastric ulcer or ulcer-related symptoms were the most frequently reported, which were treated with 18 plant species. Other gastrointestinal health problems found in local communities and the number of plant species used to treat them were abdominal pain (12 species), acid reflux (7 species), jaundice (7 species), appendicitis (6 species), flatulence (6 species), and diarrhea (5 species). Other less commonly cited ailments were gastroenteritis, liver poisoning, constipation, hemorrhoids, hematemesis, and hernia, each treated with 1 to 3 species. In total, 53 unique plant species were documented for gastrointestinal treatments. Several of these species were used to treat more than one ailment, resulting in 67 cumulative use reports across different gastrointestinal conditions. The detailed list of gastrointestinal ailments and the number of medicinal plant species used for their treatment is presented in Table 3.

Table 3. Ailment categories, number of species used, and Informant Consensus Factor (ICF) of medicinal plants to treat gastrointestinal problems by Toraja people in South Sulawesi, Indonesia

Gastrointestinal ailment categories	Number of citations (Nur)	Number of species used (NT)	ICF	Most frequently used species
Gastritis/gastric ulcer	51	18	0.66	*Ageratum conyzoides* L.
Abdominal pain	45	12	0.75	*Psidium guajava* L.
Acid reflux (GERD)	9	7	0.25	*Pluchea indica* (L.) Less.
Jaundice	10	7	0.33	*Ficus septica* Burm.fil.
Appendicitis	7	6	0.17	*Boehmeria cylindrica* (L.) Sw.
Flatulence	14	6	0.62	*Hyptis capitata* Jacq.
Diarrhea	7	5	0.33	*Zingiber cassumunar* Roxb.
Liver	4	3	0.33	*Apium graveolens* L.
Gastroenteritis	2	2	0.00	*Ocimum sanctum* L.
Poisoning	3	2	0.50	*Cocos nucifera* L.
Constipation	2	1	1.00	*Ananas comosus* (L.) Merr.
Hemorrhoids	2	1	1.00	*Piper umbellatum* L.
Hematemesis	1	1	0.00	*Graptophyllum pictum* (L.) Griff.
Hernia	1	1	0.00	*Alternanthera philoxeroides* (Mart.) Griseb.

Use Value (UV), Fidelity Level (FL), and Informant Consensus Factor (ICF)

Use Value (UV)

Based on the analysis of Use Value (UV), a variation in the importance of medicinal plant species was observed among informants. The highest UV was recorded for *A. conyzoides* (0.83), indicating it was the most frequently cited and widely used species. This was followed by *Chromolaena odorata* (L.) R.M.King & H.Rob. (0.79) and *Gymnanthemum amygdalinum* (Delile) Sch.Bip. ex Walp. (0.64), both of which were also commonly mentioned. Moderate UV values were found in *Jatropha curcas* L. (0.60) and *P. guajava* (0.50), while the lowest UV value (0.02) was recorded for six species, including *Casuarina junghuhniana* Miq., indicating limited citation across informants.

Fidelity Level (FL)

The result of the FL analysis showed that several species achieved the highest FL value (100%), indicating complete agreement among informants regarding their specific medicinal uses. *Acorus calamus, Corchorus capsularis* L., and *P. guajava* were consistently cited for the treatment of abdominal pain; *Amaranthus spinosus* L. and *Boehmeria nivea* (L.) Gaudich. for appendicitis; and *Leuenbergeria bleo* (Kunth) Lodé and *Acalypha indica* L. for gastritis and acid reflux (GERD). For flatulence, *H. capitata* showed a slightly lower FL (90%), yet still reflected strong informant agreement. In contrast, *J. curcas* had the lowest FL (6.67%), indicating its use for poisoning, but with greater variability in reported applications. However, the greater variability in reported applications for *J. curcas* highlights the complexity of the data.

Informant Consensus Factor (ICF)

The ICF calculation showed a high level of agreement among informants in certain ailment categories. Abdominal pain had the highest ICF value (0.75), indicating strong consensus in plant use, with *P. guajava* being the most frequently cited species. Gastritis/gastric ulcer (0.66) and flatulence (0.62) were recorded at a considerable degree, both reflecting substantial agreement; the most commonly used species were *A. conyzoides* and *H. capitata*. In contrast, lower ICF values were observed for acid reflux (GERD) (0.25) and appendicitis (0.17), with *Pluchea indica* (L.) Less. and *Boehmeria cylindrica* (L.) Sw. being the most frequently cited species for each condition, respectively, indicating greater variability in plant use.

Discussion

The level of knowledge and understanding of informants regarding the use of medicinal plants is linked to their profiles. In this study, 23 males (54.76%) and 19 females (45.24%) were interviewed, with males being more dominant in traditional healing practices. This phenomenon is obviously influenced by a patriarchal culture that favors the passing down of healing knowledge to sons, as well as men's greater mobility, which allows them to access medicinal plants in nature. This finding is in agreement with Supit et al. (2023), who found male dominance in traditional medicine in Wawona Village, South Minahasa. Informants aged 61-70 had a deeper understanding of medicinal plants, which is consistent with the report from Soraya (2022), who noted that people in this age group tend to inherit knowledge across generations. However, Ikaditya (2016) suggested that the knowledge of medicinal plants is not always directly related to age or education, since factors like life experience and memory also play a role. Most informants (69%) were farmers, contributing the most information about medicinal plants due to their direct interaction with nature. Supit et al. (2023) also found that farmers had the highest knowledge of plant use. On average, informants could name 14 species of medicinal plants, with 83% mentioning more than 10 species and 38% over 15 species. This result is in line with previous ethnobotanical studies indicating that naming more than 10-15 species reflects strong local knowledge (Martin 1995; Alexiades 1996; da Silva et al. 2019). Based on the results, this study revealed that the knowledge of medicinal plant use in the community remains high and well-preserved, with a strong indication of being influenced by

age, gender, profession, and the intergenerational tradition of using plants as medicine. However, this knowledge is increasingly at risk of erosion due to modernization and reduced transmission to younger generations. Preserving such traditional knowledge is vital not only for cultural identity but also for safeguarding biocultural heritage. This biocultural heritage is deeply connected to local ecosystems, highlighting the intricate and profound relationship between culture and nature.

This study highlights the significant role of medicinal plants in treating gastrointestinal (GI) ailments within the local community of Toraja. A total of 53 species were recorded, covering 43 genera and 29 families, with the most frequently represented families being Zingiberaceae, Asteraceae, Amaranthaceae, and Euphorbiaceae. The relatively high utilization of these families reflects patterns observed in other ethnobotanical studies, indicating a broader trend in traditional plant use driven by local availability, perceived effectiveness, and cultural knowledge. For instance, Ralte et al. (2024) documented Asteraceae (11 species), Zingiberaceae (9 species), and Euphorbiaceae (8 species) as the most commonly used families in Mizoram, India, including for GI ailments. Similarly, Shah et al. (2013) identified Amaranthaceae (9 species) as the dominant family in Makerwal and Gulla Khel, Pakistan, also contributing to treatments for gastrointestinal issues. These similarities underscore the consistent and important role of these plant families in traditional healthcare systems. The use of medicinal plants to treat gastrointestinal ailments among the Toraja people also reflects patterns observed among other Indonesian ethnic groups. Yusro et al. (2021) reported that the Dayak Muara in West Kalimantan extensively used various species, particularly from Zingiberaceae, to treat diarrhea and stomach disorders.

Similarly, Khastini et al. (2021) documented the reliance of the Baduy community in West Java on medicinal plants from families such as Zingiberaceae and Euphobiaceae for gastrointestinal health. Pitopang et al. (2024) also observed overlapping ethnobotanical knowledge among the Kaili Ledo in Central Sulawesi, who commonly utilized species from Asteraceae and Euphorbiaceae for similar purposes. These parallels suggest a recurring ethnomedicinal pattern in Indonesia's diverse cultural landscapes, potentially shaped by similar ecological resources and long-standing oral traditions. In the case of Toraja, intergenerational knowledge transmission still occurs through oral traditions, daily observation, and mentorship from elders to younger family members. However, this process has weakened due to increasing reliance on modern healthcare systems, formal education, and reduced interest among youth in traditional practices.

Herbaceous species accounted for 55% of the total medicinal plants used. These plants are preferred because they are easy to find, grow quickly, and are believed to have medicinal value throughout all parts of the plant. Additionally, the communities often believe that herbaceous plants provide quick relief for common ailments, are safe due to their long history of use, and can be easily prepared with minimal processing. This pattern is consistent with findings from other regions, such as in Okhaldhunga, eastern Nepal, where 46% of medicinal plants reported were herbaceous (Karki et al. 2023), and in Haripur, northern Pakistan, where the proportion reached 41.25% (Siddique et al. 2021). The high Use Value (UV) of *A. conyzoides* (0.83) reflects its widespread use in traditional medicine, as seen in its mention across various ailment categories (Phillips et al. 1994). *Ageratum conyzoides* contains flavonoids such as kaempferol, quercetin, ageconyflavone, sinensetin, and amenoflavone, which have demonstrated antibacterial, anti-inflammatory, gastroprotective, and antiulcerogenic properties, thereby supporting its traditional use for treating gastritis or gastric ulcer (Aladdin et al. 2017; Thorat et al. 2018; Kotta et al. 2020; Rajput et al. 2022; Li et al. 2025). The Fidelity Level (FL) analysis shows strong consensus on specific uses, such as *A. calamus, C. capsularis,* and *P. guajava* for abdominal pain, all with 100% FL. *Acorus calamus* contains terpenoids such as α-asarone and β-asarone, which have been reported to exhibit antibacterial, antidiarrheal, carminative, and antispasmodic properties, potentially supporting its traditional use for treating abdominal pain (Rajput et al. 2014; Umamaheshwari and Rekha 2018). *P. guajava* is rich in flavonoids such as quercetin, which demonstrate antidiarrheal (Ugbogu et al. 2022). In contrast, *J. curcas* showed the lowest FL (6.67%) for poisoning, indicating more diverse or inconsistent applications (Friedman 1986). The highest Informant Consensus Factor (ICF) was found for abdominal pain (0.75), reflecting a strong agreement among informants on the use of *P. guajava*. Lower ICF values for acid reflux (0.25) and appendicitis (0.17) suggest greater variability and less shared knowledge in these categories (Heinrich 1998). Several medicinal plant species identified in this study deserve special attention, especially those that are endemic or have not been thoroughly studied for their phytochemical properties. For example, *Pigafetta elata* (Mart.) H.Wendl. is a unique species native to this region and could have medicinal potential, but its bioactive compounds are still largely unknown. Likewise, *C. capsularis* and *L. bleo* are traditionally used for medicinal purposes, but there is limited scientific information about their specific chemical components and biological effects. These gaps emphasize the need for further research to support conservation and sustainable use of these species. Additionally, these results highlight the importance of incorporating local ecological knowledge into future pharmacological studies. By focusing on underexplored species with high cultural significance, such as *P. elata* and *L. bleo*, this study provides a foundation for future drug discovery based on ethnobotanical data.

The most commonly used plant part was the leaves (46%). This preference is deeply rooted in local traditions and beliefs that leaves are considered the most potent and safest plant part for medicinal use. This is due to their ease of processing, versatility in application, and long-standing presence in traditional healing practices. Several studies support this trend, including Simbo (2010) in Babungo, Northwest Region, Cameroon, where 65% of plant uses involved leaves, and Koch et al. (2015) in the East Sepik province of Papua New Guinea, with more than 30%. These studies highlight that leaves are favored for their

high content of bioactive compounds, year-round availability, ease of access, and simple preparation. Additionally, leaf harvesting does not require uprooting or cutting the plant, unlike roots or rhizomes, making it a more sustainable option. The predominant preparation methods, boiling (53%) and crushing (16%), further reinforce the continuity of ethnomedicinal practices across regions. Boiling is widely practiced for its effectiveness in extracting active compounds into liquid form, making them easier to consume or apply. It is considered a safe, economical, and flexible method, as mentioned by Lestari and Susanti (2019), who found that the Suku Anak Dalam in Bengkulu, Indonesia, favor boiling for its ability to release more compounds and eliminate harmful pathogens. Meanwhile, the crushing method, often applied to leaves, is known to be a practical and quick alternative method requiring no special tools. It is commonly used for topical or oral applications, as reported by Demie et al. (2018) in Southeast Ethiopia, where 20% of preparations of herbal medicine involved crushing. This method is particularly effective due to the water-soluble nature of bioactive compounds in leaves.

The study underscores the potential for bioprospecting, particularly among understudied species that exhibited high Use Value (UV), Fidelity Level (FL), Informant Consensus Factor (ICF), and endemic species, such as *A. conyzoides, A. calamus, C. capsularis, B. nivea, L. bleo, C. junghuhniana, Flacourtia rukam* Zoll. & Moritzi, and *A. indica.* Their ethnomedicinal relevance suggests promising pharmacological properties yet to be fully explored. As demonstrated by the development of modern drugs like quinine from *Chincona* sp. and artemisinin from *Artemisia annua* L., traditional knowledge can serve as a foundation for new therapeutic discoveries (Hsu 2006; Gachelin et al. 2017; Cao and Xia 2023). The findings of this study carry important conservation implications. The growing reliance on wild-harvested species raises ecological concerns. To mitigate this, sustainable harvesting, cultivation initiatives, and wider clinical validation are crucial to ensure both the preservation of biodiversity and the continuity of ethnobotanical knowledge. Therefore, integrating ethnobotanical documentation with biodiversity conservation strategies is essential to safeguard both cultural heritage and ecosystem health. This is particularly urgent in Toraja, where cultural shifts, land-use changes, and younger generations' decreasing familiarity with medicinal plants pose a threat to the continuity of traditional practices. However, community-based efforts can play a significant role in preserving traditional knowledge and biodiversity, making the local community an integral part of the conservation process. By highlighting the medicinal uses of locally known plants, this study contributes to efforts aimed at sustaining both ecological integrity and cultural resilience through community-based conservation and knowledge revitalization.

In conclusion, this study highlights the rich ethnobotanical knowledge of the Toraja community in treating gastrointestinal disorders, documenting 53 medicinal plant species, with *A. conyzoides, P. guajava,* and *A. calamus* being the most frequently cited. Key species contain bioactive compounds, such as flavonoids and terpenoids, which support their traditional use and potential for pharmacological validation. We recommend: (i) conservation and community cultivation of species like *C. capsularis* to reduce pressure on wild populations; (ii) clinical and phytochemical validation of the most cited plants; (iii) documentation and educational programs to maintain intergenerational knowledge transfer; (iv) integration of validated remedies into local healthcare and biodiversity management. These actions can protect cultural heritage and biodiversity, promote sustainable use of medicinal plants, and guide future ethnopharmacological research in Toraja.

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Ethnogastronomy of *bubur pedas* of the Malay community in North Sumatra, Indonesia and its contribution to local food security

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Abstract. *Nasution J, Pasaribu N, Silalahi M, Harahap RH. 2025. Ethnogastronomy of* bubur pedas *of the Malay community in North Sumatra, Indonesia and its contribution to local food security. Asian J Ethnobiol 8: 312-323.* The majority of Indonesian traditional foods are undocumented and endangered due to globalization and shifting diets. *Bubur pedas* ('spiced' or 'spicy porridge'), a Ramadan dish of the Malay community in North Sumatra, Indonesia, with over a century of history, is also at risk of of being forgotten or losing its prominence due to demographic change and cultural assimilation. Therefore, this study applied an ethnogastronomic method to determine key species' ingredients in *bubur pedas* and the contribution to local food security. Fieldwork was conducted from January to December 2023 in six historical Malay Sultanate areas, namely Medan, Langkat, Deli Serdang, Serdang Bedagai, Batubara, and Tanjungbalai. Data were collected through semi-structured interviews, participatory observations, and plant identification with 27 key informants. In total, 76 plant species from 33 families were documented, with leaves as the most common ingredient (45%). The results showed a strong correlation between Use Value (UV) and Relative Frequency of Citation (RFC), with 12 key species identified using the Relative Importance (RI) Index. The primary ingredients, determined based on high RI indices, were *Allium cepa, Arachis hypogaea, Coriandrum sativum, Cocos nucifera, Curcuma longa, Cuminum cyminum, Daucus carota, Etlingera elatior, Ipomoea batatas, Manihot esculenta, Oryza sativa,* and *Solanum tuberosum*. Mapping the results onto FAO's food security pillars showed that *bubur pedas* contributes to species availability, easy access through markets and household gardens, nutritional and medicinal value, as well as seasonal resilience. The study highlighted the role of Malay culinary heritage in sustaining culturally embedded, ecologically resilient food practices.

Keywords: *Bubur pedas*, ethnogastronomy, food security, local food, Malay

INTRODUCTION

Indonesia, the largest archipelagic country in Southeast Asia, harbors a rich bio- and cultural diversity shaped by over 1,300 ethnic groups and a wide range of ecological zones (Widyatmoko 2018; Utomo and McDonald 2020). Over 5,300 traditional foods have been documented in Indonesia throughout history, based on the convergence of natural resources, historical events, cultural values, and modes of preparation (Surya and Tedjakusuma 2022). In many local cultures, food serves a dual purpose as both nourishment and medicine, reflecting the food-medicine continuum where plants serve dual nutritional and healing functions (Adelman and Haushofer 2018). Traditional food systems, developed through generations of Traditional Ecological Knowledge (TEK), remain essential in linking biodiversity with cultural identity and food security (Rani et al. 2025). However, globalization and urbanization increasingly threaten this knowledge, leading to the gradual erosion of indigenous food practices among younger generations (Feldman and Wunderlich 2023; Yao et al. 2023). To address this, ethnobiology provides a framework to document and interpret community interactions with biodiversity through knowledge, practices, and beliefs (Ludwig and El-Hani 2020). Within this discipline, ethnogastronomy integrates ethnobotany, anthropology, and food studies to explore the cultural, ecological, and health dimensions of traditional food, aligning with Article 8(j) of the Convention on Biological Diversity (CBD) that emphasizes the preservation of TEK for sustainable development and local food security (CBD 2016; Stryamets et al. 2021).

Medan, the third-largest metropolitan city in Indonesia on the island of Sumatra, was historically part of the Deli Sultanate, a region once inhabited predominantly by the Malay ethnic group. Today, however, the Malay population in Medan is relatively small compared to other major ethnic communities such as the Batak, Javanese, Nias, Chinese, and Minangkabau (Ananta et al. 2015; Damanik 2020). The Malay population is largely concentrated along the east coast of North Sumatra, resulting in limited visibility and transmission of their cultural expressions, including traditional foods that remain localized within specific communities (Perry 2017). Unlike the Riau Malays, whose culinary heritage has been examined in terms of commodification, authenticity, and sustainability amid modernization pressures, the Malay food in Medan

remains underrepresented despite its strong potential to preserve cultural identity and adapt to contemporary food systems without compromising authenticity (Mardatillah et al. 2019). Among the traditional dishes investigated in this study from an ethnogastronomic perspective is *bubur pedas* (literally, 'spiced' or 'spicy porridge'). Preparing and consuming *bubur pedas* has been a Ramadan tradition since at least 1909, intended to help maintain physical well-being during daily fasting periods of 13-14 hours. The inclusion of spices reflects the belief that 'spicy food' confers health benefits (Simbolon et al. 2025). Although *bubur pedas* has been studied among the Aceh Tamiang Malays, where 17 plant species were recorded (Navia et al. 2020), its preparation and plant composition among the Malays of Medan remain undocumented. Variations in ingredients and cooking methods likely reflect the distinct cultural identity of the Medan Malay community. Medan represents the main population center of Malays on the west coast of Sumatra, yet traditional knowledge of *bubur pedas* preparation techniques remains largely undocumented.

The preparation and transmission of traditional foods are increasingly recognized as part of biocultural diversity, the interconnectedness of biological, cultural, and linguistic diversity that sustains resilient socio-ecological systems (Swiderska et al. 2022). Within this framework, food practices embody not only ecological knowledge but also collective identity and cultural memory. Moreover, the continued use of local crops and culinary methods reflects food sovereignty, emphasizing the rights of communities to define their own food systems based on culturally appropriate practices and locally available biodiversity (FAO 2019; Blake 2022). Placing *bubur pedas* within these perspectives helps to explain how Malay food traditions support both cultural resilience and local food security. Yet, as urbanization, migration, and cultural assimilation continue, there is a growing risk that specific culinary knowledge, such as the choice of ingredients, balance of spices, and ceremonial uses, could gradually fade if not carefully documented through ethnogastronomic studies. Evidence for similar patterns was seen in the study on the vitality of the Malay language in North Sumatra, which reported declining transmission and shrinking daily use as younger generations shift toward majority or global languages (Pramuniati et al. 2024). This study therefore aimed to provide systematic documentation by (i) identifying the plant species used in preparing *bubur pedas*; (ii) applying the quantitative ethnobotanical indices such as Use Value (UV); Relative Frequency of Citation (RFC) as indicators of biological and cultural importance, as well as and (iii) examining the contributions of *bubur pedas* to the four pillars of local food security among the Malay community in North Sumatra, Indonesia.

MATERIALS AND METHODS

Study area

The study was conducted between January and December 2023 across six historical Malay Sultanate regions of North Sumatra Province, Indonesia. The regions include Medan City, Langkat District, Deli Serdang District, Serdang Bedagai District, Batubara District, and Tanjungbalai City, as shown in Figure 1.

The sites were selected because Malay communities in these areas continue to preserve the preparation of *bubur pedas* as part of their culinary heritage and ceremonial dish (Nasution et al. 2025). Geographically, the study sites represented a range of ecological and sociocultural contexts, extending from urban settlements (e.g., Maimun Village in Medan) to coastal zones (e.g., Tanjung Tiram and Kuala Kapias Districts) and peri-urban areas in between. These differences were not analyzed ecologically but are acknowledged as potential factors influencing the self-procurement of local plants from home gardens for the preparation of *bubur pedas*.

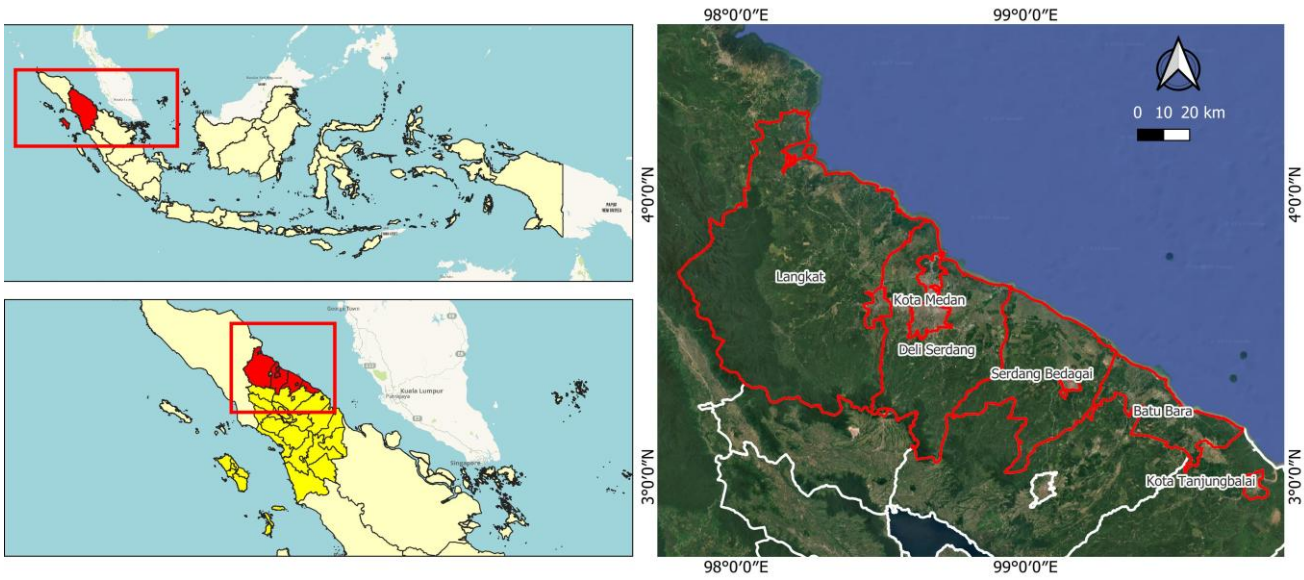

Figure 1. Location of study sites covering six historical areas inhabited by the Malay community in North Sumatra, Indonesia

Data collection

This study was designed using a qualitative or descriptive method within the framework of ethnogastronomy to examine the plant diversity and cultural significance of *bubur pedas* among Malay communities in North Sumatra. Data collection focused on documenting plant species used in the dish, including botanical and vernacular names, parts used, perceived functions (food, medicine, or both), availability status (abundant, scarce, or difficult to obtain), and sources of procurement (household gardens or markets). Ethnobotanical indices were applied to identify species of dominant cultural and biological importance. A total of 27 informants were recruited using purposive and snowball sampling, both of which were non-probability methods commonly applied in ethnogastronomic studies (Martin 2004; Motti et al. 2024).

The methods were deemed appropriate as they provided rapid access to the study population and TEK was unevenly distributed within the community, with detailed expertise concentrated among specific individuals. Eligibility criteria required informants to be at least 35 years old, have direct experience in preparing *bubur pedas*, possess detailed knowledge of the plants, including the parts and preparation methods, as well recognized within the community as custodians of culinary knowledge. Informants were selected from the five historical Malay sultanates of North Sumatra, comprising seven from Deli and five each from Langkat, Asahan, Batubara, and Serdang, to ensure balanced geographical representation. Recruitment continued until thematic saturation was achieved (Etikan 2016). Informants represented variation in gender, age, education, and occupation, as detailed in Table 1. Data were collected through semi-structured interviews, participatory observation, and plant identification. Semi-structured interviews were used to document plant species, the parts used, sources of procurement, availability, and associated cultural meanings. Participatory observation during the preparation of *bubur pedas,* combined with photographic and written documentation, captured tacit knowledge and preparation processes. Plant identification was conducted using standard taxonomic references, with nomenclature validated through Plants of the World Online (POWO). Voucher specimens were not collected due to logistical limitations arising from the study's wide geographic scope and time constraints during the fasting month.

Ethical considerations

In this study, permit was obtained from official authorities at all sites. Participation was voluntary, with oral informed consent secured before interviews and observations, while the identities of informants were anonymized. This study adhered to the International Society of Ethnobiology Code of Ethics (2006) and the Nagoya Protocol (2010) on Access and Benefit Sharing.

Data analysis

All interview and observation data were tabulated and organized in digital formats. Descriptive summaries were first generated to provide an overview of species diversity, plant parts used, availability, sources of procurement, type of utilization, and cultural functions. Quantitative ethnobotanical analysis was conducted using two standard indices, such as UV. This was aimed to measure the frequency and intensity of use of a plant based on the number mentioned by the informant (Phillips and Gentry 1993) through the formula:

$$UV = \frac{\Sigma Ui}{N}$$

Where Ui is the number of uses cited by each informant for a given species, and N is the total number of informants.

RFC is the proportion of informants who mentioned the use of a plant, signifying the level of popularity or general nature of the species (Tardío and Pardo-de-Santayana 2008), and it is calculated using the following formula:

$$RFC = \frac{FC}{N}$$

Where FC is the number of informants mentioning a species at least once, and N is the total number of informants. A set of key species that serve as indicators or distinguishing elements of the traditional dish was identified using the relative importance (RI) index (Tardio and Pardo-de-Santayana 2008), calculated according to the following formula:

$$RI = [RFC_{max} - RNU_{max}] \div 2$$

Where RFC_{max} = FC/FC_{max} denotes the RFC of a species. It is obtained by dividing the frequency of citation of a given species (FC) by the frequency of citation of the most mentioned species (FC_{max}). Similarly, RNU_{max} = NU/NU_{max} denotes the relative number of use categories. This parameter is calculated by dividing the number of use or disease categories reported for a particular species (NU) by the number of categories recorded for the species with the highest number of categories (NU_{max}).

Table 1. Sociodemographic profile of informants recruited through snowball sampling for the extraction of information regarding *bubur pedas* (N = 27)

Parameter	Category	N	%
Gender	Male	6	22.22
	Female	21	77.78
Age	35–49 years	11	40.74
	50–64 years	7	25.92
	65–79 years	9	33.34
Education	Primary school	3	11.11
	Junior high school	2	7.42
	Senior high school	16	59.25
	University graduates	6	22.22
Occupation	Housewife	14	51.85
	Teacher	4	14.81
	Office staff	2	7.42
	Private employee	4	14.81
	Artist	1	3.69
	Fisherman	2	7.42

To assess contributions of *bubur pedas* to food security, qualitative data were translated qualitatively with the four Food and Agriculture Organization (FAO) pillars, such as availability, accessibility, utilization, and stability (FAO 2019). Field data on species diversity, procurement pathways, and availability were mapped to these dimensions and interpreted through ethnogastronomic lenses. The relationship between UV and RFC was visualized using linear regression and Spearman's rank correlation (ρ). Associations between categorical variables (e.g., availability and accessibility) were analyzed using Pearson's chi-square and Fisher's exact tests. Effect size was calculated using the phi (φ) coefficient based on the number of species (N = 76), providing a standardized measure of association strength. All analyses were performed using Minitab® version 19.0.

RESULTS AND DISCUSSION

A total of 76 plant species belonging to 33 families were documented and used in the preparation of *bubur pedas* among Malay communities in North Sumatra, as detailed in Table 2 and Figure 2. Among the species' ingredients, the highest UV was documented for shallot (*Allium cepa*, UV = 4.07), coconut (*Cocos nucifera*, UV = 4.00), sweet potato (*Ipomoea batatas*) and potato (*Solanum tuberosum*) (both UV = 3.85), cassava (*Manihot esculenta*, UV =3.56), as well as torch ginger (*Etlingera elatior*, UV = 3.25). Some species achieved the maximum citation (RFC = 1.00), including coriander (*Coriandrum sativum*), coconut (*C. nucifera*), peanut (*Arachis hypogaea*), lemongrass (*Cymbopogon citratus*), turmeric (*Curcuma longa*), and torch ginger (*E. elatior*). Other frequently cited species with high RFC values (0.89-0.96) were carrot (*Daucus carota*), sweet potato (*I. batatas*), lime (*Citrus hystrix*), potato (*S. tuberosum*), ginger (*Zingiber officinale*), cumin (*Cuminum cyminum*), cassava (*M. esculenta*), mung bean (*Vigna radiata*), banana (*Musa acuminata*), and rice (*Oryza sativa*). *Bubur pedas* was prepared using a wide range of plant species and parts that Malay communities harvested. Leaves were the most frequently used part (45%), followed by seeds (17%), fruits (14%), tubers (9%), and rhizomes (8%), while flowers, stems, endosperm, sprouts, and bark appeared in smaller proportions, as detailed in Figure 3. Procurement patterns revealed that more than half of the ingredients were sourced from local markets (55%). Nearly half were obtained directly from home gardens or yards (45%), as presented in Figure 3. In the markets, most of the ingredients were readily available in abundance (81%), and only a small fraction, approximately 19% were difficult to find. Statistical analysis confirmed a strong association between species availability and accessibility (χ^2 = 14.23, df = 1, p<0.001; Fisher's exact test, p<0.001). The corresponding phi coefficient (φ = 0.43, N = 76) indicates a moderate-to-large effect size, suggesting that species abundance strongly influences their accessibility in markets and household yards.

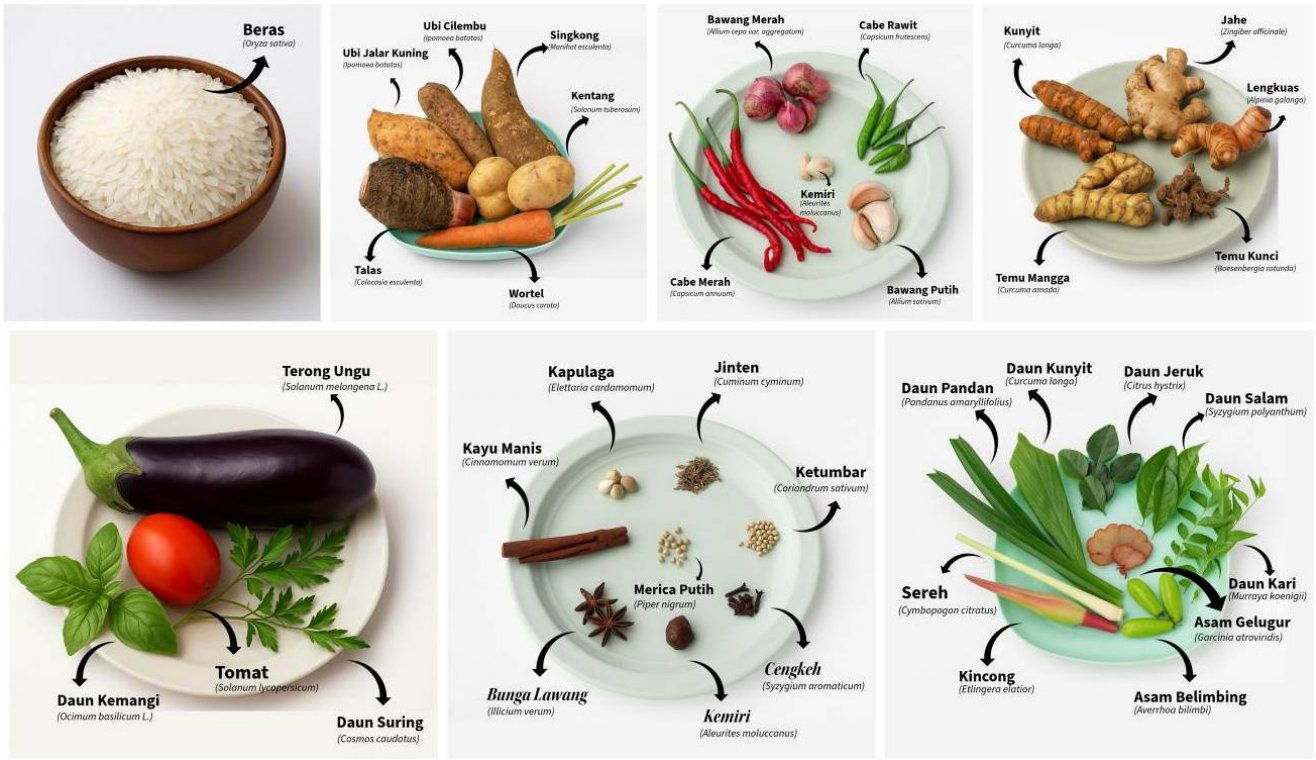

Figure 2. Some food ingredients in Malay *bubur pedas* are from different plant species and parts used

Table 2. List of plant species ($N = 76$) used in the preparation of *bubur pedas* by Malay communities in North Sumatra, Indonesia

Family	Scientific name	Local name	PPU	Availability	Accessibility	Use(s)	UV	RFC
Acanthaceae	*Ruellia tuberosa* L.	*Kencana ungu*	Leaf	Scarce	Yard	F, M	0.04	0.04
Amaranthaceae	*Amaranthus tricolor* L.	*Bayam*	Leaf	Abundant	Market, Yard	F	0.15	0.07
Amaryllidaceae	*Allium cepa* L.	*Bawang merah*	Tuber	Abundant	Market	F	4.07	0.81
Amaryllidaceae	*Allium fistulosum* L.	*Bawang Prei*	Leaf	Abundant	Market	F	0.22	0.07
Amaryllidaceae	*Allium sativum* L.	*Bawang putih*	Tuber	Abundant	Market	F, M	1.89	0.63
Anacardiaceae	*Mangifera indica* L.	*Mangga*	Leaf	Abundant	Yard	F	0.22	0.11
Apiaceae	*Cuminum cyminum* L.	*Jintan putih*	Seed	Abundant	Market	F	2.67	0.89
Apiaceae	*Pimpinella anisum* L.	*Jintan manis*	Seed	Abundant	Market	F	2.00	0.67
Apiaceae	*Coriandrum sativum* L.	*Ketumbar*	Seed	Abundant	Market	F, M	2.00	1.00
Apiaceae	*Centella asiatica* (L.) Urb.	*Pegagan*	Leaf	Abundant	Yard	F	0.52	0.26
Apiaceae	*Apium graveolens* L.	*Seledri*	Leaf	Abundant	Market	F, M	1.22	0.41
Apiaceae	*Daucus carota* L.	*Wortel*	Tuber	Abundant	Market	F	2.89	0.96
Arecaceae	*Cocos nucifera* L.	*Kelapa*	Endosperm	Abundant	Market	F	4.00	1.00
Araceae	*Colocasia esculenta* (L.) Schott	*Keladi, Talas*	Tuber	Abundant	Market	F	2.11	0.70
Araliaceae	*Polyscias scutellaria* (Burm.f.) Fosberg	*Mangkokan*	Leaf	Abundant	Yard	F, M	1.41	0.70
Araliaceae	*Polyscias fruticosa* (L.) Harms	*Berlangkas, Paku geroda*	Leaf	Scarce	Yard	F	0.30	0.15
Asteraceae	*Acmella repens* (Walter) Rich.	*Kancing baju*	Leaf	Scarce	Yard	F, M	0.11	0.04
Asteraceae	*Pluchea indica* (L.) Less.	*Beluntas*	Leaf	Abundant	Yard	F, M	0.67	0.22
Asteraceae	*Cosmos caudatus* Kunth	*Daun suring, Ulam raja*	Leaf	Rare	Yard	F	0.15	0.07
Asteraceae	*Elephantopus scaber* L.	*Tapak liman*	Leaf	Abundant	Yard	F, M	0.44	0.22
Brassicaceae	*Brassica oleracea* L.	*Kol*	Leaf	Abundant	Market	F	0.07	0.04
Caricaceae	*Carica papaya* L.	*Pepaya*	Leaf	Abundant	Market, Yard	F	0.22	0.07
Clusiaceae	*Garcinia atroviridis* Griff. ex T. Anderson	*Asam gelugur*	Leaf	Rare	Yard	F	0.44	0.15
Convolvulaceae	*Ipomoea batatas* (L.) Poir.	*Ubi jalar*	Tuber	Abundant	Market	F	3.85	0.96
Cucurbitaceae	*Cucurbita moschata* Duchesne	*Labu*	Fruit	Abundant	Market	F	2.37	0.59
Cucurbitaceae	*Sechium edule* (Jacq.) Sw.	*Labu jipang*	Fruit	Abundant	Market	F	0.89	0.22
Euphorbiaceae	*Aleurites moluccanus* (L.) Willd.	*Kemiri*	Seed	Abundant	Market	F	0.56	0.19
Euphorbiaceae	*Manihot esculenta* Crantz	*Ubi kayu*	Leaf, Tuber	Abundant	Market, Yard	F	3.56	0.89
Fabaceae	*Phaseolus vulgaris* L.	*Buncis*	Fruit	Abundant	Market	F	0.15	0.04
Fabaceae	*Glycine max* (L.) Merr.	*Kacang kedelai*	Seed	Abundant	Market	F	0.96	0.48
Fabaceae	*Canavalia ensiformis* (L.) DC.	*Kacang koro*	Seed	Abundant	Market	F	0.07	0.04
Fabaceae	*Vigna unguiculata ssp. sesquipedalis* (L.) Verdc.	*Kacang panjang*	Fruit	Abundant	Market	F	0.22	0.07
Fabaceae	*Arachis hypogaea* L.	*Kacang tanah*	Seed	Abundant	Market	F	2.00	1.00
Fabaceae	*Vigna angularis* (Willd.) Ohwi & H. Ohashi	*Kacang merah*	Seed	Abundant	Market	F	0.89	0.30
Fabaceae	*Parkia speciosa* Hassk.	*Petai*	Fruit	Abundant	Market	F	0.07	0.04
Fabaceae	*Leucaena leucocephala* (Lam.) de Wit	*Petai cina*	Seed	Abundant	Market	F	0.07	0.04
Fabaceae	*Vigna radiata* (L.) R. Wilczek	*Kacang hijau*	Seed, Sprouts	Abundant	Market	F	1.78	0.89
Gnetaceae	*Gnetum gnemon* L.	*Melinjo*	Leaf	Abundant	Yard	F	0.37	0.19
Lamiaceae	*Premna serratifolia* L.	*Babuas, Buas-buas*	Leaf	Scarce	Yard	F, M	1.67	0.56
Lamiaceae	*Coleus amboinicus* Lour.	*Bangun-bangun*	Leaf	Scarce	Yard	F, M	0.44	0.15
Lamiaceae	*Ocimum basilicum* L.	*Kemangi*	Leaf	Abundant	Market, Yard	F	0.89	0.30
Lamiaceae	*Vitex trifolia* L.	*Lagundi*	Leaf	Scarce	Yard	F	0.30	0.15
Lamiaceae	*Ocimum tenuiflorum* L.	*Ruku-ruku*	Leaf	Scarce	Yard	F	0.33	0.11
Lauraceae	*Cinnamomum verum* J.Presl	*Kayu Manis*	Bark	Abundant	Market	F, M	0.74	0.37
Moringaceae	*Moringa oleifera* Lam.	*Kelor*	Leaf	Abundant	Yard	F, M	0.15	0.07
Musaceae	*Musa acuminata* Colla	*Pisang kepok*	Fruit	Abundant	Market	F	1.78	0.89
Myrtaceae	*Syzygium aromaticum* (L.) Merr. & L.M. Perry	*Cengkeh*	Flower	Abundant	Market	F, M	1.48	0.74
Myrtaceae	*Psidium guajava* L.	*Jambu biji*	Leaf	Abundant	Yard	F, M	0.30	0.15
Myrtaceae	*Syzygium malaccense* (L.) Merr. & L. M. Perry	*Jambu bol*	Leaf	Abundant	Yard	F	0.15	0.07
Myrtaceae	*Syzygium polyanthum* Miq.	*Salam*	Leaf	Abundant	Yard	F, M	1.04	0.52
Myristicaceae	*Myristica fragrans* Houtt.	*Pala*	Seed	Abundant	Market	F, M	0.56	0.56
Pandanaceae	*Pandanus amaryllifolius* Roxb.	*Pandan*	Leaf	Abundant	Yard	F	0.37	0.19
Piperaceae	*Piper nigrum* L.	*Merica, Lada*	Seed	Abundant	Market	F	1.85	0.93
Poaceae	*Zea mays* L.	*Jagung*	Fruit	Abundant	Market	F	2.22	0.74
Poaceae	*Oryza sativa* L.	*Padi, Beras*	Fruit	Abundant	Market	F	2.67	0.89
Poaceae	*Cymbopogon citratus* (DC.) Stapf	*Serai*	Leaf	Abundant	Market, Yard	F, M	1.00	1.00
Polygonaceae	*Persicaria odorata* (Lour.) Sojak*	*Cendohom, Kesum*	Leaf	Rare	Yard	F	0.07	0.04
Rhamnaceae	*Ziziphus jujuba* L. (Lam).	*Pule*	Leaf	Scarce	Yard	F, M	0.07	0.04
Rubiaceae	*Morinda citrifolia* L.	*Mengkudu*	Leaf	Abundant	Yard	F, M	0.37	0.19
Rubiaceae	*Paederia foetida* L.	*Sikentut*	Leaf	Scarce	Yard	F, M	1.78	0.59
Rutaceae	*Citrus hystrix* H. Perrier	*Jeruk purut*	Leaf	Abundant	Yard	F	1.93	0.96
Rutaceae	*Murraya koenigii* (L.) Spreng.	*Kari*	Leaf	Abundant	Yard	F	0.52	0.26
Schisandaceae	*Illicium verum* Hook. F.	*Bunga lawang*	Flower	Abundant	Market	F	0.96	0.48
Solanaceae	*Capsicum annuum* L.	*Cabe merah/ hijau*	Fruit	Abundant	Market	F	0.59	0.30
Solanaceae	*Solanum tuberosum* L.	*Kentang*	Tuber	Abundant	Market	F	3.85	0.96
Solanaceae	*Solanum americanum* Mill.	*Leunca, Meranti*	Leaf	Scarce	Yard	F	0.11	0.04
Solanaceae	*Solanum torvum* Sw.	*Rimbang*	Fruit	Abundant	Yard	F	0.11	0.04

Solanaceae	*Solanum melongena* L.	*Terong ungu*	Fruit	Abundant	Market	F	0.15	0.07
Zingiberaceae	*Amomum compactum* Sol. Ex Maton	*Kapulaga*	Seed	Abundant	Market	F, M	0.67	0.33
Zingiberaceae	*Alpinia galanga* (L.) Willd.	*Lengkuas*	Rhizome	Abundant	Market, Yard	F, M	2.22	0.74
Zingiberaceae	*Boesenbergia rotunda* (L.) Mansf.	*Temu kunci*	Rhizome	Scarce	Market, Yard	F, M	0.78	0.26
Zingiberaceae	*Curcuma longa* L.	*Kunyit*	Leaf, Rhizome	Abundant	Market, Yard	F, M	2.00	1.00
Zingiberaceae	*Curcuma amada* Roxb*	*Temu mangga*	Rhizome	Rare	Market, Yard	F, M	1.00	0.33
Zingiberaceae	*Etlingera elatior* (Jack) R.M.Sm.	*Kecombrang*	Flower	Abundant	Yard	F, M	3.25	1.00
Zingiberaceae	*Zingiber officinale* Roscoe	*Jahe*	Rhizome	Abundant	Market, Yard	F, M	1.93	0.96
Zingiberaceae	*Zingiber zerumbet* (L.) Roscoe ex Sm.	*Lempuyang*	Rhizome	Abundant	Market	F, M	0.44	0.22

Note: PPU: Plant part used. F: Food. M: Medicine. UV: Use value. RFC: Relative frequency of citation. Species with an asterisk (*) are prioritized for conservation

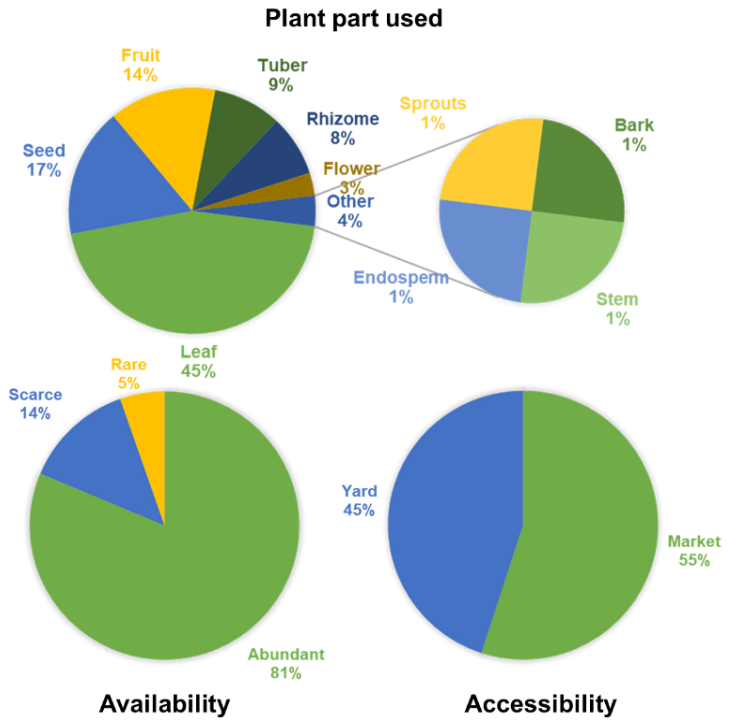

Figure 3. Percentage of accessibility, availability, and plant parts used in the preparation of *bubur pedas* by Malay communities in North Sumatra, Indonesia

The categorization of plant species based on UV and RFC values revealed that the majority were classified as low categories, as presented in Figure 4.A. Out of 76 species, 48 (63.2%), 23 (30.3%), and 5 (6.6%) fell into the low, medium, and high UV categories, respectively. A similar pattern was observed for RFC, with 43 (56.6%), 16 (21.1%), and 17 (22.4%) classified as low, medium, and high. However, a strong, positive, and significant relationship (p<0.001) was observed between UV and RFC, as signified from a high coefficient of determination (R^2 = 0.78) and Spearman's correlation coefficient (ρ = 0.95). The relationship showed that species with higher UV also tended to have greater RFC. As a result, the plants most frequently cited by informants had the greatest diversity and intensity of uses. The most important species that characterize the identity of *bubur pedas* ingredients were determined based on the RI index, using the 75th percentile as the threshold. A total of twelve species were identified as the key or signature ingredients of the dish, representing those with RI values above the 75th percentile threshold (RI>0.75), as shown in Figure 5. These species represent the plants most important to, most frequently cited by, and most commonly used among informants in the preparation of *bubur pedas*. Coconut (*C. nucifera*), tuber crops such as *I. batatas* and *S. tuberosum*, together with staple rice (*O. sativa*), showed high RIs (≥0.90). Spices and aromatic plants, including *C. longa*, *E. elatior*, *C. cyminum*, and *C. sativum*, confirmed the strong role of Zingiberaceae and Apiaceae in shaping the characteristic flavor of the dish. Legumes (*A. hypogaea*) and widely consumed vegetables, namely *D. carota*, *A. cepa*, and *M. esculenta,* also ranked within the top group. These plant species represent the most versatile and frequently cited ingredients with their functional importance in the preparation of *bubur pedas*. Food security was approached through four interconnected dimensions, including availability, accessibility, utilization, and stability, following the framework provided by the FAO. The ethnogastronomic information and field observations were translated into these four pillars to capture the role of *bubur pedas* in supporting local food systems. Among the pillars, availability was the most accomplished task, with many plant species being either abundant in markets or readily cultivated in household gardens. Detailed indicators and results are summarized in Table 3.

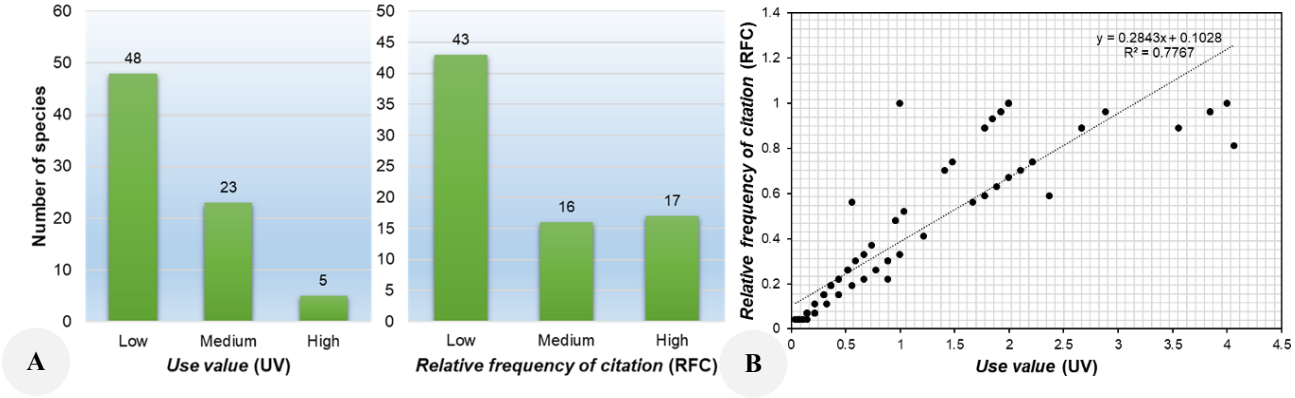

Figure 4. Ethnobotanical indices (UV, RFC) were used for the ethnogastronomic context. A. Categorization of UV and RFC for several plant species used in the preparation of *bubur pedas*. Low: 1<UV, 0.4<RFC; Medium: 1≤UV≤3, 0.4≤RFC≤0.8; High: UV>3, RFC>0.8. B. Relationship between UV and RFC using a linear regression curve showing a moderate-to-high value of the coefficient of determination (R^2)

Table 3. Food security indicators based on FAO's four pillars, with its connection to *bubur pedas* in the Malay communities in North Sumatra, Indonesia

FAO pillars	Field indicators	Results
Availability	Species richness; Multiple sources (market and home garden)	76 species from 32 families; 52% obtained from markets, 48% from home gardens
Accessibility	Distance and cost of access	Markets are located nearby; home gardens provide free and direct access (specifically for leaves)
Utilization	Plant parts and nutritional value	Leaves (>45%) are the main parts used; Members of *Zingiberaceae* provide health benefits; Tubers and vegetables serve as sources of carbohydrates and bioactive compounds.
Stability	Seasonality and scarcity	Leaves are abundant during the rainy season, while tubers are more widely used in the dry season. Three species are becoming scarcely available: *Cosmos caudatus* (still can be found in some home gardens but is limited), *Curcuma amada* (only available through flower bouquet vendors), and *Persicaria odorata* (reported in coastal areas but not found during field surveys).

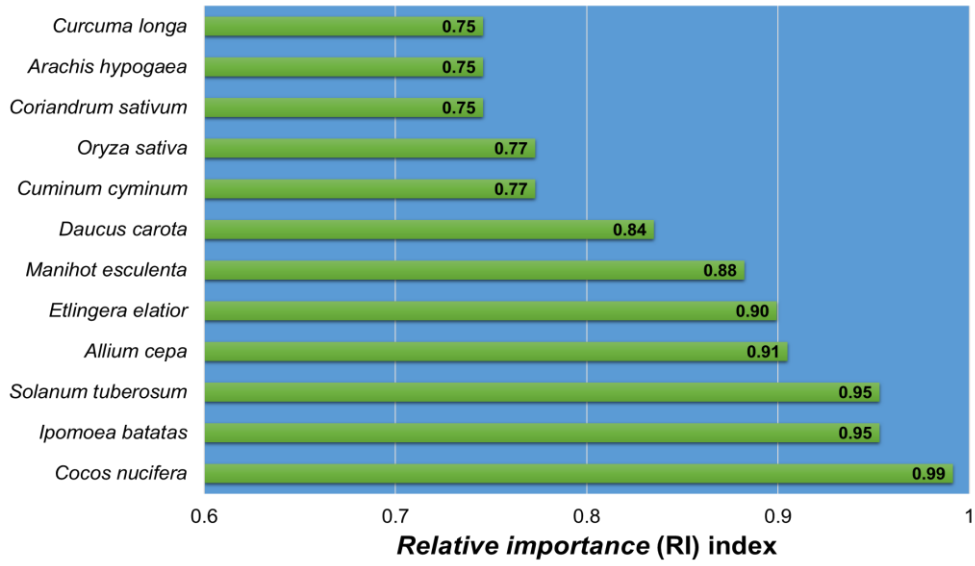

Figure 5. Twelve key ingredients of plant species in Malay *bubur pedas* based on the highest (75% percentile) of the RI Index in the Malay communities in North Sumatra, Indonesia

Discussion

The richness of traditional food reflects the abundance of native natural resources and the traditional knowledge shared across ethnic and cultural boundaries (Turner et al. 2011). The idea of porridge, cooked grains served as a soft dish, has ancient roots and appears in many cultures around the world. Historical records show that communities have prepared porridge for thousands of years. Despite regional variations, this food shares common traits, including being simple to prepare, versatile, and nutritious. Most are prepared from locally grown grains, enriched with ingredients available in the surrounding environment. The popularity of porridge lies in the ease of preparation and adaptability. The choice of grain varies by region, producing flavors that range from savory to spicy (Wijesekara 2025). In an effort to enrich the documentation of Indonesia's cultural heritage, particularly traditional food that remains underexplored and vulnerable to obscurity or loss, an ethnogastronomic method was applied to study *bubur pedas*. In this study, women, particularly housewives, were the majority of informants for *bubur pedas* preparation, emphasizing the crucial role in preserving gastronomic heritage. Similar results have been documented globally, for example, in the Coastal Cilento region, Italy, where women comprised 63% of informants having knowledge of traditional dishes (Motti et al. 2024). In Castilla-La Mancha, Spain, women also preserved gastronomic traditions while contributing to agri-food sectors and hospitality (García-Henche et al. 2024). Among the Huni Kuĩ indigenous community in the Amazon, Brazil, the culinary activities were strictly female domains, acting as primary transmitters of biodiversity knowledge and maintainers of food systems (Pilnik et al. 2021). In Mollo District, East Nusa Tenggara, Indonesia, the expertise in traditional cuisine was in line with ecofeminist perspectives, promoting women as key agents for sustainable gastronomic tourism through domestic skills and local food promotion (Mandaru et al. 2025).

The preparation of *bubur pedas* comprised 76 plant species across 33 families, an exceptionally high diversity for a single porridge-based dish. Among the species, seven were assigned as key ingredients with high UV and RFC values. Fabaceae and Apiaceae were the most represented families, contributing legumes, beans, and aromatic spices that are essential for both nutrition and flavor. Legumes such as *A. hypogaea*, *V. radiata*, and *Glycine max* provide plant-based proteins, energy, and texture to the dish while *C. cyminum*, *C. sativum*, and *Apium graveolens* supply distinctive aromas and digestive benefits (Ropashree et al. 2025; Safitri et al. 2025). Members of Zingiberaceae played a central role in shaping the sensory identity of the dish through color, aroma, and pungency, and also exemplify the food-medicine continuum with anti-inflammatory, carminative, and immune-enhancing properties (Deng et al. 2022; Inta et al. 2023). Poaceae anchored the dish through its staple cereals (*O. sativa, Zea mays*), showing cultural and nutritional values within Malay and broader Asian food signatures (Mohapatra et al. 2025). Arecaceae, represented by *C. nucifera* (coconut milk), imparted a milky texture and savory taste to *bubur pedas*. At the species level, several plants were identified as signature ingredients, each contributing distinct culinary and medicinal values. *Curcuma longa* provided the characteristic yellow hue and was also revered for its therapeutic attributes (Jikah and Edo 2025). *Etlingera elatior* and *Z. officinale* added fragrance, supportive digestion, and warmth sensation (John et al. 2025). *Allium cepa* and *Piper betle* enhanced aroma and flavor integration within the dish (Li et al. 2022; Patra et al. 2022). In this study, *bubur pedas* relied heavily on leaves (45%), especially from Fabaceae, Lamiaceae, and Asteraceae, which provided the leafy greens and herbs. The use of green leaves in porridge is not unique to the Malay community, as similar practices have been documented elsewhere. Leafy ingredients were shown to lower glycaemic response in Sri Lankan porridges (Senadheera and Ekanayake 2013) and to improve micronutrient intake, particularly iron and zinc, in South African porridges (Kruger et al. 2015).

From a broader perspective, the high-RI ingredients identified in *bubur pedas* possess well-documented nutritional and phytochemical properties that can support physiological resilience during prolonged fasting. Some examples included *C. longa* (turmeric) which contains curcumin and associated polyphenols with strong anti-inflammatory and antioxidant activities. Recent reviews and meta-analyses have demonstrated that curcumin supplementation can reduce inflammatory markers and oxidative-stress biomarkers in humans (Peng et al. 2021; Kaur et al. 2024). *Etlingera elatior* (torch ginger) is particularly rich in phenolic and flavonoid compounds, exhibiting significant antioxidant capacity in vitro, which may help mitigate oxidative stress during fasting (Mutmainah et al. 2024). *Cocos nucifera* (coconut) provides medium-chain fatty acids, such as lauric acid, that act as readily available energy sources, while its water is rich in electrolytes (potassium, sodium, and magnesium) that promote rehydration and energy balance, factors essential for recovery at *iftar* and maintaining metabolic stability during fasting (Patil and Benjakul 2018; Mat et al. 2022). Finally, *O. sativa* (rice) offers rapidly digestible carbohydrates and, depending on its variety and processing, contains resistant starch fractions that modulate glycemic response and support steady postprandial energy release, key aspects for sustaining energy following fasting periods (Takahashi et al. 2022).

Although the dish is called *bubur pedas*, analysis showed that chili peppers (*Capsicum annuum*) did not rank among the most important ingredients, with relatively low values for both UV (0.59) and RFC (0.30). While chilli was recognized for adding heat, it was not consistently regarded as a defining or indispensable component of the recipe. The usage was mostly limited to flavoring, in contrast to species such as *C. nucifera*, *C. longa*, or *E. elatior*, which combined culinary, medicinal, and cultural roles as evidenced from their high RI values. Informants also noted that spiciness (chili) can be adjusted to personal preference or even omitted entirely, whereas ingredients such as coconut milk and turmeric are regarded as indispensable for maintaining the authentic character of *bubur pedas*.

This observation reflects what can be described as a "spicy paradox", a misconception in which the term *pedas* (spicy) actually refers to the complex, aromatic warmth produced by ginger, turmeric, and pepper, rather than the capsaicin-derived heat of chili.

The strong and significant association between availability and accessibility indicates two complementary procurement pathways. Markets provide year-round access and diversity of ingredients, yet dependence on them can expose households, especially low-income ones, to price and supply fluctuations. In contrast, home gardens offer a subsistence buffer, ensuring stable access to essential plants and reducing reliance on external sources. This combination reflects a dual food strategy in which Malay households balance market convenience with self-provisioning to maintain culinary traditions amid shifting socio-economic conditions. This pattern was consistent with broader ethnobotanical results, where plants of lower economic value or strong cultural significance were more often cultivated in small home plots for family use rather than for trade (Appamaraka et al. 2023; Phatlamphu et al. 2023). Although the species contribute little to market economies, owing to seasonal nature and limited circulation, household food security was sustained and dietary diversity was enriched. These practices show a self-sufficient food system, where plants are grown mainly to support needs and preserve cultural traditions, rather than to earn money from selling (Taniushkina et al. 2024). Within this framework, the persistence of growing scarce species in home gardens shows how Malay communities not only preserve the culinary authenticity of *bubur pedas* but also strengthen resilience against market fluctuations. One of the informants also confirmed that by stating, *"If all the leaves are available at home, we don't need to go to the market; we just pick them"*. Although most recorded species are readily available through cultivation or local markets, *Curcuma amada* and *Persicaria odorata* were relatively scarce and maintained mainly in household gardens. Their low citation values suggest limited cultivation and a gradual decline in local knowledge of their culinary use. This trend may result from low market demand and replacement by more accessible substitutes. Promoting small-scale cultivation, homegarden propagation, and community seed exchange could help sustain these species while preserving the traditional food practices associated with *bubur pedas* (Pushpakumara et al. 2020; Shao et al. 2021).

A strong and significant positive correlation was shown between UV and RFC (R^2 = 0.78; ρ = 0.95) even though most species showed relatively low values for both indices. This indicates that widely used species are more frequently cited, reflecting a consensus on their importance within the community. In simple terms, species with broader versatility tend to be cited more frequently by a greater number of informants (Tardío and Pardo-de-Santayana 2008). This interpretation was consistent with previous studies. For example, Qaseem et al. (2018) reported a positive UV-RFC correlation (R^2 = 0.60) in studies of indigenous medicinal flora in Pakistan, while Ahmed et al. (2018) found a similar pattern (Spearman's ρ = 0.60) when assessing the local importance of tree species in the North Western Himalayas. Conversely, Afrianto (2025) documented a weak or non-significant relationship between the Number of Uses (NU) and RFC in the ethnobotany of Javanese home gardens, suggesting that plant importance in some contexts may be more influenced by cultural or symbolic functions than by frequency of mention. These reports reinforced that the interpretation of ethnobotanical indices must remain context-specific. Documenting traditional knowledge, therefore, serves as an essential foundation for further investigations. Future studies may explore the bioactive compounds of the most frequently used species (Reyes-García 2010) and assess their nutritional and functional properties (Zebua et al. 2025), given that many plants in *bubur pedas* are traditionally perceived as both food and medicine.

Briefly, the preparation of *bubur pedas* began with the selection of spices, which were dry-roasted to intensify aroma and flavor. The roasted mixture was then ground and sieved into a fine powder. Grains of rice were combined with diced tubers, leafy vegetables, and aromatics such as lemongrass. This mixture was sautéed together with the ground spices and fresh herbs, followed by pounding or grinding to achieve a uniform consistency. The fine spice-rice mixture was sieved once more before being simmered with coconut milk and vegetables. The final dish was a thick, aromatic porridge, distinguished by a yellowish color, rich in spices, and spicy. During Ramadan, it is prepared either for family consumption or shared with the wider community, as detailed in Figure 6. Other similar dish, such as *bubor paddas* from Kalimantan, was promoted as emergency food and long-term food supplies (Rusiardy et al. 2014). A single serving delivered substantial energy (618.11 kcal) and protein (7.13 g) while maintaining a low glycemic index (Lestari and Purwayantie 2018). Besides nutrition, anthropological studies also reported a rich vocabulary (lexicon) in the *bubur pedas*' recipe, ingredients, preparation methods, and tools (Maharani et al. 2023). These suggest a great chance of *bubur pedas* becoming a popular traditional dish that is both nutritious and culturally distinct.

In conclusion, this study reported a comprehensive botanical documentation of *bubur pedas*, a traditional dish by the Malay communities in North Sumatra. In a time of declining biodiversity and rapid dietary modernization, traditional cuisines remain vital in maintaining both ecological balance and cultural identity. The case of *bubur pedas* shows that Indonesia's culinary heritage supports sustainable food practices consistent with global goals, including the United Nations Sustainable Development Goals, SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land), and the FAO's four pillars of food security. Malay food traditions illustrate that biodiversity, nutrition, and cultural values can coexist within everyday cooking, where conservation is embedded naturally in community life rather than imposed by policy.

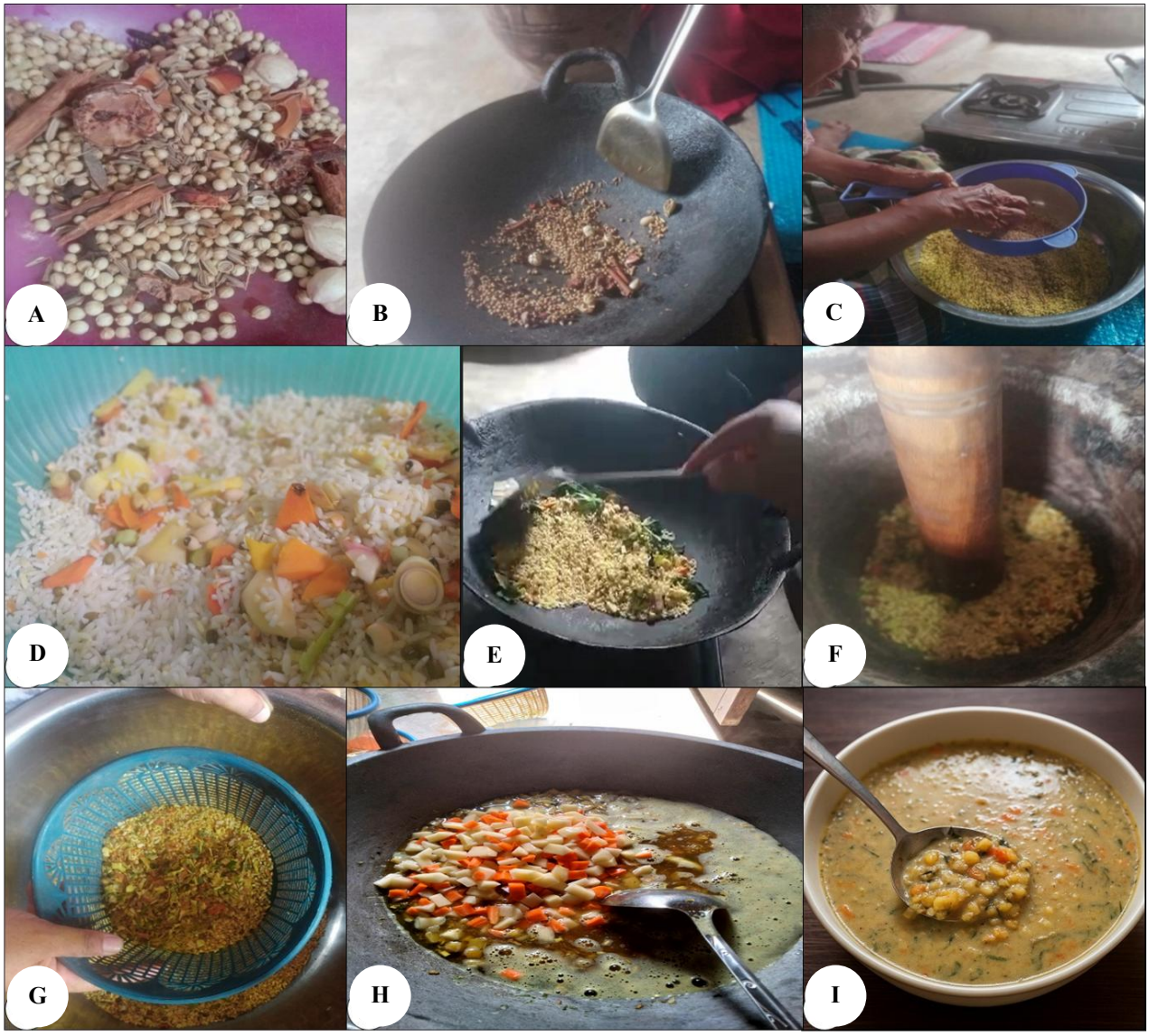

Figure 6. Preparation process of Malay *bubur pedas* in North Sumatra, Indonesia. A. Raw spices before processing, B. Roasting of spices, C. Grinding and sieving of roasted spices, D. Mixing rice with tubers, vegetables, and aromatics, E. Frying spice-rice mixture with herbs, F. Pounding for finer consistency, G. Sieving to refine texture, H. Simmering mixture with coconut milk and vegetables, I. Final appearance of *bubur pedas*, a traditional Malay dish of 'spiced' or 'spicy porridge'

This study added the important role of ethnogastronomy within ethnobiology as a lens for understanding food as both a biological resource and a cultural expression. The preparation of *bubur pedas*, combining ingredients from home gardens and local markets, reflects a flexible, reciprocal relationship between people and plants, a living form of biocultural conservation. Such practices sustain food sovereignty, enabling Malay communities in North Sumatra to preserve their food choices and identity amid the growing uniformity of global diets. Importantly, *bubur pedas* also incorporated from the region's core local food plants, i.e. cassava, maize, mung bean, peanut, soybean, and sweet potato, which are central to North Sumatran agrodiversity and align with Indonesia's *Pangan Lokal Berkelanjutan* (Sustainable Local Food Program). These crops provide accessible sources of carbohydrates and plant-based protein while reinforcing food diversification and local self-sufficiency. At the community level, the wide range of plant species used in *bubur pedas* reflects household adaptability to seasonal and market fluctuations. The dish's distinct identity lies not in the heat of chili but in the layered texture of tubers and leafy greens, and in the gentle warmth of local spices, a culinary expression of ecological adaptability. The communal preparation of *bubur pedas* during Ramadan and other gatherings further strengthens cultural continuity and intergenerational knowledge transfer. Theoretically, this work positions ethnogastronomy as a bridge connecting biodiversity conservation, cultural resilience, and food security. Practically, it highlights the value of supporting home-garden cultivation, protecting local crop varieties, and integrating traditional food knowledge into regional food

policy and education. Nonetheless, this study faced limitations: voucher specimens were not collected due to logistical constraints, and food security analysis relied on qualitative mapping rather than nutritional testing. Future research should address these gaps by exploring local perceptions, nutrient composition, and the ecological benefits of these traditional food plants. Despite these limitations, *bubur pedas* stands as more than a meal, it is a viable symbol of Malay identity and a reminder that sustainable food futures can emerge from the biodiversity and wisdom preserved in local kitchens.

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Community health promotion for sustainable well-being using the wisdom of traditional medicine practitioners of Isan, Thailand

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Abstract. *Phon-Ngam P. 2025. Community health promotion for sustainable well-being using the wisdom of traditional medicine practitioners of Isan, Thailand. Asian J Ethnobiol 8: 324-331.* This study employed a Participatory Action Research (PAR) approach to investigate and promote community health and sustainable well-being through the ethnomedical knowledge and practices of Traditional Medicine Practitioners (TMPs) in Isan, Thailand. The study aimed to: (i) explore the roles, knowledge, and practices of TMPs in enhancing community health and resilience, (ii) develop and implement a community health promotion model grounded in traditional medicine wisdom, and (iii) evaluate the effectiveness and sustainability of the implemented model. Participants included TMPs, community leaders, health officers, and local villagers. Data were collected through in-depth interviews, focus group discussions, participatory brainstorming sessions, and observation of traditional health practices. Findings indicate that TMPs play a crucial role in preserving cultural heritage, providing accessible and contextually relevant healthcare, and strengthening community cohesion and resilience. However, challenges such as limited recognition by formal health systems, insufficient mechanisms for knowledge transfer to younger generations, and weak integration with contemporary medical practices were identified. The proposed health promotion model emphasizes systematic documentation of traditional knowledge, collaborative engagement between TMPs and public health officers, and capacity-building initiatives to ensure the sustainable application of ethnomedicine in community health. The integrated model enhanced intergenerational learning, cultural preservation, and community empowerment while aligning with Sustainable Development Goals (SDGs 3, 4, 11, and 15). Integrating traditional medicine wisdom through participatory approaches strengthens cultural identity and contributes to ethnobiology, ethnomedicine, and community health promotion. The findings provide adaptable insights for similar cultural and ecological contexts worldwide, supporting sustainable well-being and complementing modern public health systems.

Keywords: Ethnomedicine, local wisdom, sustainable well-being, traditional knowledge

INTRODUCTION

Health promotion has become a global priority as communities strive for sustainable well-being amidst rapid social, economic, and environmental transitions (Murray et al. 2019, 2020). In Southeast Asia, particularly in the Isan region of Thailand, traditional medicine has long played a central role in maintaining community health (Tongma and Srisopha 2020; Onchomchan 2020). Rooted in indigenous knowledge, local practitioners provide not only preventive and curative care but also culturally grounded approaches that align with the holistic needs of their populations (Phon-ngam et al. 2024).

Traditional medicine in Isan extends beyond herbal remedies. It encompasses practices, beliefs, and social values that connect health to cultural identity and community resilience (WHO 2019). Studies indicate that communities widely trust Traditional Medicine Practitioners (TMPs) for common illnesses, chronic conditions, and spiritual health, yet their contributions remain underrepresented in formal health systems (Peltzer et al. 2020). Globally, the integration of traditional medicine into health systems is recognized as vital for achieving Sustainable Development Goals (SDGs), particularly those linked to health equity, cultural preservation, and sustainable development (WHO 2013).

The World Health Organization (WHO) has emphasized that strengthening universal health coverage requires incorporating traditional medicine, especially in areas where biomedical services are limited (WHO 2019). Regional studies highlight that Thailand can enhance the application of indigenous health knowledge, creating inclusive models that strengthen both primary healthcare and community participation (Lim et al. 2020; Nguyen et al. 2021). Despite this recognition, TMPs are often marginalized in national health policies due to structural barriers, such as limited policy support, insufficient research engagement, and broader global trends that undervalue indigenous knowledge systems (Kongthong et al. 2021).

The Isan Region presents a particularly valuable context for research. The areas share cultural and linguistic roots, along with long-standing healing traditions that persist despite modernization (Phon-ngam et al. 2024). Rural communities face challenges, including poverty, migration, and limited healthcare infrastructure, highlighting the potential role of TMPs in bridging formal and informal health systems to strengthen community well-being (Murray et al. 2019). Drawing on TMPs' wisdom allows communities to create culturally relevant and cost-effective strategies that

enhance trust, participation, and sustainability in health promotion (Smith and Chen 2023).

This study employs Participatory Action Research (PAR) to explore the integration of TMPs' knowledge into community health promotion in selected areas of Thailand (Baum et al. 2016). PAR is a practical and inclusive methodology that engages communities in identifying problems, co-creating solutions, and sustaining outcomes (Reddy et al. 2023). By involving TMPs, local leaders, health officials, and community members, this approach ensures that traditional knowledge is not only documented but also actively applied in meaningful ways (Nguyen et al. 2019; Lim et al. 2020). Importantly, PAR contributes to empowerment by positioning local stakeholders as active agents of change rather than passive recipients of external interventions

The significance of this research lies in three main areas. First, it addresses a critical gap by systematically examining Traditional Medicine Practitioners' (TMPs) contributions to community health promotion in the transboundary Isan–Lao context (Phon-ngam et al. 2024). Second, it contributes to theoretical debates on how indigenous knowledge informs sustainable health models that align with both local culture and global health frameworks (Murray et al. 2019). Third, it provides practical implications for policy and practice, offering models that policymakers, educators, and healthcare providers can adapt to strengthen community health systems (Tongma and Srisopha 2020; Smith and Chen 2023).

This study emphasizes the importance of recognizing and integrating traditional medicine wisdom into contemporary health promotion. By leveraging TMPs' strengths through participatory approaches, communities in Thailand can enhance resilience, equity, and sustainability in health. This research contributes not only to local development but also to global discussions on sustainable health promotion, cultural preservation, and the integration of indigenous wisdom into modern systems of care. The objectives were to: (i) Investigate the role and practices of traditional medicine practitioners in promoting community health and sustainable well-being, emphasizing ethnomedical knowledge and cultural practices; (ii) develop and implement a community health promotion model using traditional medicine wisdom; (iii) evaluate the implementation of community health promotion models using traditional medicine wisdom.

MATERIALS AND METHODS

This study employed a Participatory Action Research (PAR) approach to explore and document the ethnomedicine knowledge of Traditional Medicine Practitioners (TMPs) in the Isan region and to integrate this knowledge into sustainable community health promotion. Conducted between January and August 2024, the research focused on three rural districts in Loei, Udon Thani, and Buriram Provinces in the northeastern region of Thailand, purposively selected for their active traditional medicine practices, cultural richness, and strong community engagement. The study emphasized both the preservation of traditional knowledge and its contribution to sustainable community health systems.

PAR was selected because it ensures that communities are active participants in defining problems, generating solutions, and applying knowledge, thereby fostering empowerment and sustainability. This approach is particularly suitable for ethnomedicine research, as it respects cultural norms, promotes intergenerational knowledge transmission, and strengthens community capacity.

Participants

A total of 48 participants were recruited, including TMPs, community residents, and local public health officers. Participants were selected using purposive sampling based on three criteria: residence in the study area for at least ten years, direct experience with traditional medicine (as practitioners, patients, or collaborators), and willingness to engage in all stages of the PAR process. The sample size was determined by the principle of data saturation, ensuring that data collection continued until no new themes emerged. Although interviewers were aware of participants' identities during data collection, confidentiality was strictly maintained by excluding personal identifiers in transcripts, analysis, and reporting. The characteristics of participants and data collection details are summarized in Table 1.

Table 1. Participant characteristics and data collection summary

Role/group	n	Sex (M/F)	Age range (years)	Province	Data type	No. of sessions	Avg. duration (min)
Traditional Medicine Practitioners (TMPs)	15	8/7	35-70	Khon Kaen, Mukdahan, Nakhon Phanom	In-depth interview	15	60-90
Community leaders	9	6/3	40-65	Same as above	Focus Group Discussion (FGD)	3	90
Health officers	6	2/4	30-55	Same as above	Interview	6	45-60
Local villagers	18	9/9	25-70	Same as above	Observation, FGD	3	60
Total	48	25/23					

Data collection

Multiple qualitative techniques were employed to ensure methodological triangulation and depth of understanding. Data were collected from 48 participants, including Traditional Medicine Practitioners (TMPs), community residents, and local public health officers across three provinces in northeastern Thailand. The study used (i) in-depth interviews, (ii) Focus Group Discussions (FGDs), and (iii) participatory workshops.

For in-depth interviews, semi-structured questions were designed to explore the roles, experiences, and challenges of TMPs, as well as community perceptions of traditional healing and health promotion. Sample guiding questions included: "How do you transfer your traditional knowledge to younger generations?" and "What challenges do you face in integrating traditional practices with public health programs?" Each interview lasted 45-60 minutes.

FGDs were conducted with groups of TMPs and community members across generations to discuss the sustainability of traditional medicine and community well-being. Each FGD included 6-8 participants and lasted approximately 90 minutes. Discussions focused on cultural transmission, health-seeking behavior, and community collaboration.

Participatory workshops were organized in each province to co-develop strategies for sustainable cultivation and documentation of traditional knowledge. Each workshop consisted of three sessions: (i) sharing experiences and challenges in local health practices, (ii) group analysis and prioritization of sustainable approaches, and (iii) collaborative planning for community health promotion. The workshops were facilitated by the research team with support from community leaders and health officers using participatory tools such as brainstorming, ranking, and mapping. Data were recorded through audio recordings, observation notes, and workshop outputs. Data saturation was achieved when no new codes or themes emerged.

Research phases

The research was implemented in three phases: (i) Phase 1: Exploration of knowledge and practices documenting TMPs' knowledge, practices, and community acceptance. (ii) Phase 2: Development and implementation of a community health model, participatory workshops, and working group meetings to co-create and apply a sustainable health promotion model. (iii) Phase 3: Evaluation of the implementation of community health promotion models using traditional medicine wisdom

Data analysis

Data were transcribed and analyzed using thematic analysis (Braun and Clarke 2006). NVivo 12 software (QSR International) supported coding and theme development. Themes included (i) TMPs' knowledge and practices, (ii) community acceptance and health outcomes, and (iii) challenges and opportunities for integrating ethnomedicine into health promotion. Member checking and triangulation enhanced credibility and rigor.

An inductive narrative thematic analysis approach was employed following Braun and Clarke (2006). All interviews were audio-recorded, transcribed verbatim, and participants were invited to review and confirm interpretations through member checking to ensure credibility.

Ethical considerations

Ethical approval was obtained from the Institutional Review Board of Shinawatra University, Thailand. Written informed consent was obtained from all participants prior to participation. Anonymity and confidentiality were maintained throughout data collection, analysis, and reporting**.**

RESULTS AND DISCUSSION

Role and practices of Traditional Medicine Practitioners (TMPs)

Findings from the in-depth interviews revealed that Traditional Medicine Practitioners (TMPs) in the Isan region provide healthcare based on ethnomedicine knowledge inherited through generations. Their learning processes are primarily oral and experiential, emphasizing observation, memorization, and apprenticeship. Treatments often involve compound formulas combining multiple herbs tailored to specific illnesses.

Insights from the Focus Group Discussions (FGDs) confirmed that TMPs play a critical role in preserving cultural identity, providing accessible healthcare, and enhancing community resilience. Community members expressed deep trust in TMPs and viewed traditional healing as complementary to modern medicine.

Data from the Participatory Action Research (PAR) workshops further highlighted challenges, including declining youth participation, insufficient documentation, inconsistent dosages, and limited formal recognition from the public health system. Participants collaboratively identified opportunities for integration through participatory forums, collaborative training, school herbal gardens, and public engagement via learning media and community caravans.

Development and implementation of a community health promotion model

Based on Phase 1 findings, a three-component community health promotion model was developed to strengthen sustainable well-being through education, participatory engagement, and application of ethnomedicine, addressing integration challenges with local public health systems**.** The community health promotion model can be summarized in Table 2.

The three models complement each other. Model 1 enhances practical skills and engages youth. Model 2 ensures knowledge preservation and broad accessibility. Model 3 strengthens community engagement and public awareness, supporting holistic and sustainable well-being**.**

The presents comparative summary of Knowledge, Attitudes, and Practices (KAP) outcomes across the three

models was shown in Table 3, which summarizes the baseline KAP outcomes of participants across the different health promotion models, collected prior to any intervention. Table 3 provides an overview of participants' initial knowledge, attitudes, and practices. These trends highlight that while each model strengthens different aspects of community health, the integrated approach ensures intergenerational learning, cultural preservation, and community self-reliance.

Evaluation of implementation

The three-component model was evaluated for participant satisfaction, engagement, knowledge acquisition, and sustainability. The reported outcomes reflect participants' perceptions rather than objectively measured improvements in community health. Table 4 presents KAP outcomes of all 48 participants, assessed using a structured survey developed in collaboration with PAR groups. The survey was administered directly to participants during PAR sessions. Overall, the evaluation confirms that the integrated model effectively enhanced traditional medicine knowledge, reinforced community participation, and promoted sustainable well-being. Qualitative feedback emphasized increased confidence, practical skills, and understanding of ethnomedicine among participants, particularly in youth and community engagement contexts.

The study demonstrates that a structured, three-component model combining school-based activities, learning media, and community dissemination can systematically apply local ethnomedicine knowledge to promote sustainable community health. The integrated approach strengthens intergenerational learning, cultural preservation, and community self-reliance while aligning with multiple SDGs (3, 4, 11, and 15). The findings support the effectiveness of participatory models for embedding traditional knowledge into contemporary health promotion strategies.

Table 2. A three-component community health promotion model

Model	Key activities	Target participants	Main outcomes	SDGs alignment
1. Promoting Herbal Knowledge Among Youth	Hands-on workshops, school herbal gardens, integration into curriculum	Students, teachers, volunteers	Improved practical herbal skills, teamwork, and health awareness	SDG 3, SDG 4, SDG 15
2. Learning Media and Knowledge Dissemination	Books, e-learning materials, dissemination to schools, libraries, TM associations	Students, community members	Knowledge acquisition, accessibility, and long-term preservation	SDG 3, SDG 4, SDG 15
3. Dissemination to the community	Health check-ups, herbal treatments, workshops, exhibitions, and collaboration with public health officers	Community members, TMPs, and public health officers	Increased public awareness, knowledge use, and community engagement	SDG 3, SDG 11, SDG 15

Note: The alignment with Sustainable Development Goals (SDGs) is detailed as follows. For rows 1 and 2 (SDG 3, 4, 15), SDG 3 (Good Health and Well-being) is supported by enhanced community access to healthcare and preservation of traditional practices; SDG 4 (Quality Education) is addressed through intergenerational knowledge transfer, participatory learning, and community workshops; SDG 15 (Life on Land) is linked to sustainable cultivation and conservation of medicinal plants. For row 3 (SDG 3, 11, 15), SDG 3 focuses on community health improvement; SDG 11 (Sustainable Communities) reflects strengthened social cohesion and collaborative community initiatives; SDG 15 emphasizes conservation of biodiversity and sustainable use of local medicinal plants. The proposed model is adaptable to other culturally and ecologically similar communities through systematic documentation and participatory engagement.

Table 3. Summary of Knowledge, Attitudes, and Practices (KAP) outcomes across health promotion models

Model	Knowledge	Attitude	Practice	Key observation
1. Promoting Herbal Knowledge Among Youth	High	Moderate	Moderate	A hands-on approach enhanced practical skills and engagement
2. Learning Media and Knowledge Dissemination	Moderate	Moderate	Low	Improved knowledge acquisition and long-term preservation
3. Dissemination to the community	High	High	High	Strong overall improvement through participatory community-wide engagement

Table 4. Participant satisfaction and engagement scores

Model	Satisfaction (Mean/5)	Engagement (Mean/5)	Knowledge acquisition (Mean/5)	Sustainability/ Integration (Mean/5)	Qualitative summary
1. Promoting Herbal Knowledge Among Youth	4.62	4.65	4.60	4.58	High satisfaction and engagement reported; KAP data indicate only moderate practical application; hands-on mentorship needed to enhance youth practice
2. Learning Media and Knowledge Dissemination	4.50	4.40	4.55	4.35	Clear and usable materials; moderate dissemination; supports long-term learning
3. Dissemination to the community	4.47	4.42	4.50	4.35	High satisfaction and engagement; stronger community awareness and practice

Note: Table 4 scores are based on a validated 16-item survey using a 5-point Likert scale. Items assessed Satisfaction, Engagement, Knowledge Acquisition, and Sustainability/Integration. Higher scores indicate greater satisfaction, engagement, and application of knowledge. KAP: Knowledge, Attitudes, and Practices

Discussion

Role of Traditional Medicine Practitioners (TMPs)

The findings indicate that TMPs in Isan contribute significantly to sustainable community health through holistic practices, encompassing herbal medicine, ritual therapies, and physical rehabilitation. While declining youth interest and limited formal recognition present challenges, participatory interventions such as school-based herb programs and learning media foster intergenerational knowledge transfer.

TMPs play a central role in providing culturally relevant health services within the community. However, integration with formal health systems remains weak. To strengthen collaboration, mechanisms such as joint training programs, referral systems, and co-designed health initiatives can be considered. Comparative insights from other regions, such as India and South Africa, demonstrate that structured integration of traditional practitioners with formal health services enhances both service delivery and community trust (Chaturvedi et al. 2021). These findings support the applicability of the proposed community health promotion model in culturally similar contexts, emphasizing the value of participatory engagement and collaborative frameworks

These results align with Community Empowerment Theory (Zimmerman 2021), demonstrating that engagement and skill-building enhance both individual and collective capacity. Similarly, Experiential Learning Theory supports the effectiveness of hands-on activities in developing practical competence. The promotion of local herbal cultivation not only preserves cultural knowledge but also contributes to biodiversity and environmental sustainability, supporting SDG 3, 4, 11, and 15 (WHO 2019; National Center for Complementary and Integrative Health 2024).

Comparatively, ethnomedicine interventions in Southeast Asia, such as school-based herbal education in Vietnam and community health caravans in Laos , reported similar trends in knowledge retention and youth engagement. (Nguyen et al. 2019) Globally, studies in India and South Africa indicate that participatory, TMP-centered approaches improve both health literacy and community cohesion, demonstrating the replicability and cross-cultural relevance of such models (Peltzer et al. 2020; Reddy et al. 2023). This suggests that TMP integration within educational and community frameworks is a consistent factor in sustainable ethnomedicine interventions.

Community health promotion models

The study's three-component model of school-based youth engagement, learning media, and community caravans demonstrates that structured, participatory, and media-supported interventions can sustainably enhance community well-being.

Model 1: Promoting herbal knowledge among youth engaged students, strengthened practical skills, and fostered health self-reliance.

Model 2: Learning media and knowledge dissemination enabled self-directed, intergenerational knowledge transfer and documented local wisdom.

Model 3: Dissemination to the community (traditional medicine caravan) enhanced public understanding, acceptance, and application of traditional remedies.

These approaches illustrate that experiential learning combined with community engagement strengthens social cohesion and cultural continuity. Similar ethnomedicine interventions across SE Asia and globally reinforce these findings, showing that multi-component, participatory models are more effective than single interventions in sustaining knowledge and practice (Onchomchan 2020; Peltzer et al. 2020). Notably, the integrated model in this study uniquely combines school-based, media, and community strategies, allowing both intergenerational learning and broad community reach, which is less emphasized in prior research. Local herbal practices also reduce reliance on industrial pharmaceuticals, highlighting both environmental and public health benefits. This aligns with studies in India where community-based herbal initiatives reduced medication costs and promoted sustainable health behaviors (Reddy et al. 2023).

As shown in Table 5, the three-component model in this study demonstrates both breadth and depth compared to prior ethnomedicine interventions in SE Asia and globally. Unlike Nguyen et al. (2019), which focused mainly on youth engagement, which emphasized community caravans, our integrated approach combines youth, media, and community engagement, enabling both intergenerational knowledge transfer and broad public participation. Global studies by

Peltzer et al. (2020) and Reddy et al. (2023) also underscore the value of participatory TMP-centered interventions, confirming that engagement, skill-building, and experiential learning are critical for sustainable ethnomedicine initiatives (Reddy et al. 2023). This comparative analysis highlights the novelty and effectiveness of the integrated model in enhancing community well-being, preserving cultural heritage, and supporting SDGs.

Evaluation of implementation

The integration of participatory and experiential approaches demonstrates significant potential for sustainable health promotion, as supported by prior studies and ethnological perspectives. The implemented community health promotion model engaged TMPs and community members effectively, resulting in positive perceived outcomes among participants. Given the short study timeframe, future longitudinal studies are recommended to evaluate long-term impacts on community health and cultural preservation.

Empowering communities: Research highlights that participatory health initiatives foster community ownership, enhance skill development, and strengthen social capital (Murray et al. 2019; Onchomchan 2020). From an ethnological perspective, empowerment is rooted in collective identity and kinship networks, which encourage shared responsibility for health outcomes.

Preserving cultural heritage: Ethnological theory emphasizes the importance of symbolic systems, rituals, and oral traditions in sustaining community identity (Closser et al. 2022). Systematic documentation and intergenerational transmission of Traditional Medical Practices (TMPs) ensure that indigenous knowledge is not only preserved but also contextualized within cultural meanings (Phon-ngam et al. 2024).

Supporting Sustainable Development Goals (SDGs): Evidence indicates that community-based health practices contribute to SDG 3 (good health and well-being), SDG 4 (quality education), SDG 11 (sustainable communities), and SDG 15 (life on land) (Smith and Chen 2023). Ethnological insights show that health and environment are intertwined through cultural adaptation and ecological knowledge, reinforcing the relevance of TMPs in achieving these global goals.

Complementing modern health systems: Studies confirm that integrating TMPs with biomedical approaches enhances accessibility and cultural sensitivity, while improving community trust in public health systems (Kongthong et al. 2021). Ethnological frameworks underline the coexistence of pluralistic medical systems, where traditional and modern practices interact dynamically to build resilience in health care delivery.

Participatory, educational, and media-based strategies emerged as effective and sustainable mechanisms for promoting holistic health, cultural preservation, and community empowerment. Compared with similar interventions in SE Asia and globally, this study highlights the added value of integrating multiple approaches, youth, media, and community caravan, in one cohesive model. In summary, the evaluation demonstrates that participatory and experiential models grounded in ethnological theory not only validate the role of TMPs in community health but also highlight their broader contributions to cultural sustainability and global development agendas.

Table 5. Comparative overview of ethnomedicine interventions

Study/Region	Intervention type	Target group	Key activities	Key outcomes	Notes/Lessons
This study (Isan, Thailand)	Three-component model: Youth, Learning Media, Community Caravan	Students, community members, TMPs	Hands-on workshops, school herbal gardens, learning media, health caravans	Increased knowledge, practical skills, engagement; intergenerational knowledge transfer; strengthened community cohesion	Integrated three approaches: participatory and media-supported, aligned with SDG 3, 4, 11, 15
Nguyen et al. (2019) (Vietnam)	School-based herbal education	Students	Workshops, herbal gardens	Improved herbal knowledge; youth engagement	Focused mainly on youth; less community-wide impact
Peltzer et al. 2020 (South Africa)	Participatory TMP-centered interventions	Local community	Training, community workshops	Improved knowledge and health literacy; strengthened cultural practices	Emphasized participatory methods; limited integration with schools or media
Reddy et al. (2023) (India)	School + community integration	Students, community	Workshops, media dissemination, community outreach	Enhanced knowledge retention, practical skills, and sustainable application	Multi-component model; shows environmental and cost benefits; similar to this study's integrated approach

Youth engagement

The study identified a declining interest among youth in traditional medicine, with many students showing limited engagement in TMP-led activities and Table 3 indicates only moderate improvement in attitudes and practice. These findings suggest that while school-based programs can raise awareness, they are insufficient alone to foster meaningful behavioral change. Structured hands-on activities, mentorship, and continuous follow-up are needed to enhance youth participation and practical application of traditional knowledge. School-based programs were the primary strategy used to introduce young people to these practices; however, these initiatives alone may not be sufficient to sustain long-term interest. To address this limitation, future research could explore innovative strategies that align with youth preferences and contemporary learning styles, such as digital platforms, gamification, and interactive participatory approaches. Such methods could complement school-based programs by making traditional medicine more engaging and accessible to younger generations.

Promoting youth engagement in traditional medicine is critical not only for preserving cultural knowledge but also for ensuring the continuity of community health practices. By integrating TMP-centered interventions with youth-focused strategies, communities can foster intergenerational learning, strengthen cultural heritage, and enhance the sustainability of community health promotion models.

Limitations and strengths

This study has several limitations that should be acknowledged. First, it focused on evaluating participants' perceptions and processes rather than objectively measured health outcomes, which limits the ability to determine the direct impact on community health. Second, the findings may not be generalizable to other regions or populations because they reflect the specific cultural and contextual characteristics of the study site. Lastly, although data saturation was pursued during fieldwork, some important viewpoints may have been overlooked, potentially affecting the comprehensiveness of the findings and limiting the scope of interpretation.

Despite these constraints, the study also demonstrates several notable strengths. The use of Participatory Action Research (PAR) effectively involved community members at every stage of the study, ensuring contextual relevance, inclusivity, and empowerment. In addition, the collaborative development of survey instruments and data collection tools with traditional medicine practitioners, local residents, and public health officers strengthened both the cultural sensitivity and the credibility of the data gathered. This participatory approach not only enhanced methodological rigor but also fostered community ownership of the research outcomes.

Recommendations

Policy recommendations should focus on strengthening the formal recognition and integration of Traditional Medicine Practitioners (TMPs) within Indonesia's public health framework. The government should establish policies that formally acknowledge TMPs as complementary health actors, ensuring their practices are regulated and monitored for quality and safety. Standardized guidelines for herbal dosages and preparation must also be developed to prevent variability in treatment effectiveness and potential health risks. This integration not only supports the sustainability of indigenous knowledge systems but also enhances accessibility to affordable healthcare in rural and remote areas.

Practical implementation efforts should prioritize educational and community-based initiatives. School programs and community herbal gardens can promote intergenerational knowledge transfer, youth engagement, and practical skills in traditional plant-based medicine. Participatory activities such as the *Traditional Medicine Caravan* could further strengthen public awareness, fostering collaboration between TMPs, communities, and local health offices. In addition, the use of educational media—such as books, digital modules, and e-learning platforms—can broaden public access to TMP knowledge and encourage self-directed, lifelong learning that supports the national agenda for community health resilience.

For future research, longitudinal and cross-cultural studies are needed to evaluate the long-term health and social outcomes of TMP-centered interventions. Such studies should analyze how community-based integration affects public health indicators, economic sustainability, and cultural preservation. Researchers should also investigate effective strategies to maintain youth involvement and succession in traditional medicine practice. Furthermore, comparative studies across regions could explore the most suitable integration models between TMP systems and modern healthcare, offering evidence-based pathways for inclusive and culturally grounded public health development.

In conclusion, this study demonstrates that participatory, TMP-centered interventions can enhance community health promotion and preserve cultural knowledge in the Isan region of Thailand. Through three complementary components—school-based herbal learning, community health caravans, and the development of learning media—the Participatory Action Research (PAR) approach successfully promoted intergenerational knowledge transfer, strengthened practical health skills, and deepened local engagement. These outcomes highlight the pivotal role of Traditional Medicine Practitioners (TMPs) in bridging indigenous wisdom with modern public health systems, contributing directly to the achievement of Sustainable Development Goals (SDGs) 3 (Good Health and Well-being), 4 (Quality Education), 11 (Sustainable Communities), and 15 (Life on Land). The findings offer practical insights for integrating traditional medicine into community-based health initiatives and present a replicable model that reinforces cultural identity, enhances youth participation, and supports the scalability and sustainability of local health promotion systems.

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Ethnobotanical memory of *Cinchona* among the Sundanese in the highland of West Java, Indonesia

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Abstract. *Wiranova A, Mulyanto D, Iskandar BS. 2025. Ethnobotanical memory of* Cinchona *among the Sundanese in the highland of West Java, Indonesia. Asian J Ethnobiol 8: 332-346.* Following the decline of *Cinchona* as a commodity after the discovery of synthetic malaria drugs after the World War II, its plantations in the Dutch East Indies (now Indonesia) experienced a drastic downturn. Some were converted into upland agricultural fields producing subtropical vegetables, causing cultural ties to the species to largely diminish. Therefore, this study examines the ethnobotanical memory of *Cinchona* among Sundanese communities in West Java, Indonesia, within a post-plantation landscape that has undergone significant land-use transformation into upland subtropical vegetable fields. Using oral history supported by archival research, interviews were conducted with 29 residents divided into two groups: those who experienced the operational period of the plantation and those without direct exposure to it. Ethnobotanical memory is conceptualized as the dynamic interaction of emotional, sensory, and bodily recollections of plants within a community. Three categories of memory narratives were identified. The first reflects emotional memory, in which *Cinchona* is associated with childhood experiences and nostalgia. The second highlights bodily memory, represented by recollections of plantation production processes, from seed selection and grafting to bark harvesting and drying. The third emphasizes sensory memory, expressed through the bitter taste of decoctions once consumed for medicinal purposes. These memories reveal the intertwined relationship between biological species and cultural practices, yet intergenerational transmission has been limited, particularly among younger residents who have never encountered the species in their daily lives. The decline of *Cinchona* populations following land-use change has accelerated this process of forgetting. Moreover, conservation efforts remain absent due to the loss of commercial value and the community's reliance on faster-return crops such as vegetables. The findings underscore the vulnerability of ethnobotanical memory in post-plantation contexts and highlight the need to integrate cultural perspectives into biodiversity conservation strategies.

Keywords: *Cinchona*, ethnobotanical memory, medicinal plant, plantation, West Java

INTRODUCTION

The global widespread of various plant species was largely driven by the Columbian Exchange, which refers to the exchange of ideas, diseases, and biological species such as animals and plants from Europe to the America following the voyages of Christopher Columbus in 15th century, which was later facilitated through European imperialism and colonialism (Fosberg 1947; Crosby 2004; Cuvi 2011; González-Orozco et al. 2023). As a result, many plants originating outside their native geographical regions were introduced, later becoming naturalized and integrated into the natural habitats of colonial territories, including Indonesia (García et al. 2022; Aslam et al. 2023). One contributing factor that led to the naturalization of these exotic plants was the competition among colonial powers in trading economically valuable commodities, particularly plantation crops, especially during the 19th century. Prior to widespread cultivation, several exotic plant species intended for plantation commodities underwent a series of botanical trials at botanical gardens including at the Bogor Botanical Garden in Buitenzorg (now Bogor) and Cibodas Botanical Garden in Cianjur (Gorkom 1883; van der Hoogte and Pieters 2014). Some of these species later dispersed beyond the garden's confines—either through deliberate cultivation in other plantation units or as escapees growing wild around Cibodas, among them is *Cinchona* (Zuhri and Mutaqien 2013).

Cinchona is a Neotropical flora native to South America, especially the Andean regions of Peru, Ecuador, Colombia, and Bolivia. Commonly known in Sundanese as '*kina'*, this plant is also referred to by the same term in Dutch, derived from the word '*quina'* used by the Quechuan people of Peru (Gachelin et al. 2017; García et al. 2022). This plant belongs to the Rubiaceae family and the *Cinchona* genus, which consists of approximately 25 species. Originating from altitudes between 1,050 and 1,500 meters above sea level in the Andes, *Cinchona* thrives under an annual rainfall of 2,000-3,000 mm, temperatures between 13.5-21°C, and daily relative humidity of 68-98%. The optimal soil for its cultivation is fertile, friable, non-rocky, rich in organic matter, and has a pH of 5.8 (Gorkom 1883; Paniagua-Zambrana et al. 2020; Wasis and Sandra 2020). In 1820, the quinine alkaloid was successfully isolated from *Cinchona*, becoming the most

effective treatment for malaria (Goss 2014; Dubey and Singh 2021; Nair 2021).

Caused by the *Anopheles* mosquito, malaria was deadly and prevalent in tropical rainforests. The demand for *Cinchona* soared, prompting European powers—especially British India and the Dutch East Indies—to compete in producing it. In the Dutch East Indies, or currently primarily Indonesia, *Cinchona* cultivation expanded from Cibodas Botanical Garden to the Cinyiruan Plantation in Pangalengan, West Java in 1855. Eventually, the commercially cultivated species were *Cinchona ledgeriana* (syn. *Cinchona calisaya* Wedd.), valued for its high quinine content, and *Cinchona succirubra* (syn. *Cinchona pubescens* Vahl), known for its robust roots and used as understock for grafting (Sukasmono 1995; Maxiselly et al. 2018; Nair 2021).

By 1872, the success of this propagation method enabled the Dutch East Indies to dominate global *Cinchona* bark supply, surpassing British India (Gorkom 1883; Goss 2014). This success was reinforced by the liberal economic policy introduced through the 1870 Agrarian Law, which encouraged massive foreign European investment in the colony. As a result, *Cinchona* plantations flourished, particularly in the highlands of West Java (Gorkom 1883; Goss 2014; Mulyanto 2022). In 1913, the Quinine Agreement was established, which served as pharmaceutical cartel to preserve the Dutch monopoly over *Cinchona* cultivation and quinine production, making Java the source of over 90% of the global *Cinchona* supply (Fosberg 1947; Goss 2014; van der Hoogte and Pieters 2014).

The golden era of Dutch *Cinchona* plantations ended in 1942 during the Japanese occupation, when the Allied forces began developing synthetic quinine to replace the plant-based product (Goss 2014). Nonetheless, *Cinchona* plantations in Java continued operating after Indonesian independence. Following nationalization in 1959, these plantations were managed by state-owned *PT. Perkebunan Nusantara*. One of such estates was the *Rotterdamsche Kina Maatschappij Tji Kembang*, located in what is now Cikembang Village, Bandung District, West Java. The plantation lasted for a century before it was illegally occupied by local residents in 1998, carried out sporadically as a reflection of a wider political phenomenon stemming from disappointment over the failure of agrarian reform efforts during the New Order government. The area then underwent a land-use transformation, shifting from a state-run *Cinchona* plantation to privately managed upland farming of subtropical vegetables. This transformation marked the area as a post-plantation landscape, an area no longer dominated by plantation power.

The situation lends itself to analysis through a historical ethnobotany approach. This approach examines the evolving relationship between humans and plants over time, shaped by ecological and cultural dynamics. Through diachronic investigation, historical ethnobotany can reveal knowledge about plants in the past by paying attention to changes in the environment, explored through historical evidence (Medeiros et al. 2014; Medeiros and Alves 2018; Petran et al. 2020; Dafni et al. 2021; Kalle and Sõukand 2023). This past relationship between plants and humans can be explored through institutional archival documents (Kalle and Sõukand 2012; Kujawska et al. 2017; Petran et al 2020; Singh et al. 2020; Saraçi and Damo 2021), folklore and songs (Cardaño and Herrero 2014; Dafni et al. 2021; Fišer 2022), as well as old literary text (Jákl 2015, 2016; Dafni and Böck 2019; Mulyanto et al. 2023, 2024). Therefore, historical ethnobotany provides an avenue for investigation within geographic landscapes where the ecological presence of certain plant species has declined or even vanished, despite once playing a significant role in the lives of surrounding communities. Nevertheless, such conditions require a combination of historical sources and testimonies from actors living in the present as conducted in this study. Therefore, this study aims to (i) trace the memories held by local residents regarding *Cinchona* species that have disappeared from Cikembang Village, and (ii) understand the interdependence between biological species and the surrounding cultural practices in a post-plantation landscape. The research is grounded in the concept of ethnobotanical memory, which synthesizes emotional, sensory, and bodily memory related to certain plants within local contexts. Using oral history supported by archival documents, this study incorporates historical ethnobotany approach in plantation studies, which generally focused on socio-economic structures (Veale 2010; Barral 2014; Gibbon et al. 2014; Battle-Baptiste 2017; Li 2017b; Bastos 2020; Besky 2024).

MATERIALS AND METHODS

Study area

This study was conducted in Cikembang Village, Kertasari Sub-district, Bandung District, West Java, Indonesia (Figure 1). The area is located at the coordinates 7°12′42″ S, 107°41′19″ E, situated in the southeast of Mount Malabar and north of Mount Papandayan, with an average elevation of 1,583 meters above sea level and a total area of approximately 1,372 hectares. The region has an average annual temperature of around 23.8°C, with minimum temperatures reaching approximately 20°C and maximum temperatures around 30°C. The average annual rainfall is approximately 2,148 mm, with the highest precipitation typically occurring in December and April.

This area was once home to a private *Cinchona* plantation known as *Rotterdamsche Kina Maatschappij Tji Kembang* (Figure 2) (Nederlandsche Staatscourant 1883), which has since become part of what is now Cikembang. The plantation was established in 1882 with an initial concession area of 589 hectares (Algemeen Landbouw Syndicaat and Zuid en West-Sumatra Syndicaat 1938), which later expanded. By the early 20th century, the plantation produced approximately 325,000 kilograms of *Cinchona* bark annually, with quinine content consistently exceeding 5%. Most of the bark was sent to the *Bandoengsche Kininefabriek* in Bandung to be processed into malaria medicine (Java-Kinabast 1905).

In 1959, this plantation was nationalized by the Indonesian government under the name of Cikembang Plantation under Government Regulation No. 19 of 1959. In 1983, the plantation area was designated as a separate administrative unit, named Cikembang Village within Kertasari Sub-district, Bandung District. However, the plantation's success was short-lived. By the mid-1980s, *Cinchona* production declined, accompanied by the gradual dismantling of its processing factory facilities. The downfall peaked in 1998 when local farmers illegally occupied the plantation concession area, replacing *Cinchona* with commercial vegetables such as cabbage, carrot, and potato. The occupation of the plantation's concession land was carried out without a contractual agreement, while a small portion of other areas in the village fell under social forestry contracts. In 2013, the plantation officially shifted its cultivation from *Cinchona* to coffee, employing intercropping with vegetables grown by farmers within the concession area. Nevertheless, the intercropping policy was strictly enforced for no more than five years. It was recorded that since 2023, plantation concessions have accounted for 72% of the village's total area, with nearly all of them being occupied by farmers (Pemerintah Desa Cikembang 2023). While it legally exists, its performance is a shadow of its former glory, now employing only three staffs (a manager, clerk, and chief foreman) and fewer than 30 seasonal laborers. Despite the land-use changes in this area, residual botanical knowledge persists among the local population. This knowledge is manifested through the ethnobotanical memory of *C. calisaya* and *C. pubescens*, which were once plantation commodities that have since undergone a drastic population decline.

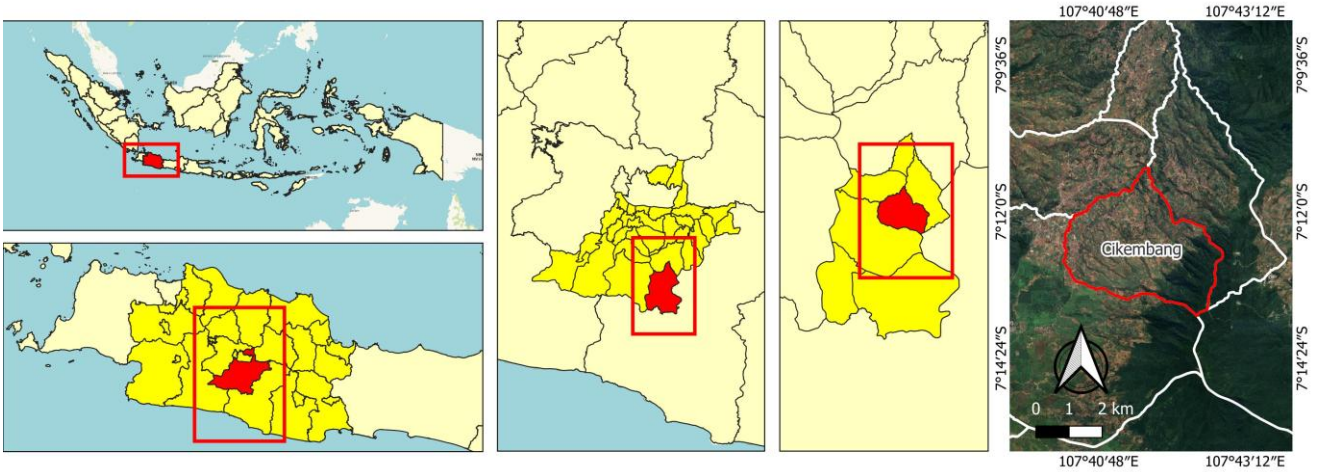

Figure 1. The map of the study area in Cikembang Village, Kertasari Sub-district, Bandung District, West Java, Indonesia

Figure 2. Cikembang *Cinchona* plantation in the colonial era. A. Aerial view of the highlands, 1932 (KITLV 408493); B. Rows of *Cinchona* trees in the plantation, 1932 (KITLV 408459); C. *Crotalaria usaramoensis* on a field where *Cinchona* will be planted later, 1923 (KITLV 408547), and D. Native foremen and laborers, 1932 (KITLV 408505)

Research procedures

This study employed a hybrid oral history method, which combines oral expressions with supporting sources in the form of historical archives (Medeiros et al. 2014; Sommer and Quinlan 2018). In the context of this research, oral expressions were obtained through interviews with informants, while historical archives consisted of textual documents such as newspapers and cultivation manuals, as well as photographic records depicting the plantation and related *Cinchona*. The research proceeded in the following stages:

Step 1. Informants were selected using the snowball sampling technique, based on recommendations from initial key informants. These key informants included the current head manager of the plantation and the village head, based on the assumption that both are stakeholder with an understanding of local context. Based on their recommendations, which further expanded through referrals from the next informants, a total of 29 residents were selected for interview. Informant recruitment was concluded once the data reached saturation, indicated by recurring testimonial narratives. The informants were then divided into the following two categories. (i) Seventeen informants who had lived alongside the actively operating *Cinchona* plantation. Of these, 12 had direct experience working on the plantation, ranging in age from 50 to 82 years old. They held various roles such as field laborers, foremen, drivers, nurses, and manager; and (ii) Twelve informants who had never been lived alongside the actively operating plantation, aged between 18 and 31 years old. This category was intended to examine the persistence of ethnobotanical knowledge among local residents whose lives no longer intersect with the presence of the *Cinchona* plantation, particularly after the disappearance of *Cinchona* from the area following land occupation beginning in 1998. All informants were asked for their consent to be interviewed and recorded, with assurances that their identities would be anonymized.

Step 2. Semi-structured interviews were conducted with the informants, guided by a prepared set of questions. This approach allowed informants greater flexibility in responding, based on their individual understanding and experiences. The questions were open-ended, covering the what, when, where, why, and how of the informants' recollections regarding *Cinchona*. These interviews were supplemented with photographic documentation from the 19th and 20th centuries, sourced from Dutch archival repositories such as KITLV (https://digitalcollections.universiteitleiden.nl) and Delpher (https://delpher.nl) and used as mnemonic devices to assist memory recall. The images presented included photographs of *Cinchona* species, scenes from the plantation during the colonial period, and tools used in production, which were subsequently identified with their corresponding local terms. This technique was employed in light of the socio-historical context surrounding the decline of the plantation, where the collapse of both the economic power and physical infrastructure of *Cinchona* cultivation led to the disappearance of supporting equipment and of *Cinchona* plants itself. Interviews and informant identification continued until data saturation was reached, indicated by the absence of new memory narratives.

Step 3. The informants' memory narratives were then categorized and coded based on the concept of ethnobotanical memory. This concept reflects a combination of emotional, sensory, and bodily memory, all of which connected to the local context of certain plants. Accordingly, the residents' memory narratives will be categorized based on these three themes. In this process, Microsoft Word and Microsoft Excel were used to facilitate the coding process and narrative writing. The scientific names of plants were validated using the Plants of the World Online (POWO) database (https://powo.science.kew.org) to ensure accurate nomenclature, including the verification of synonyms.

Data analysis

Following the in-depth interviews, the recordings were transcribed into interview transcripts. These transcripts were then categorized into codes based on specific topics and subtopics, including direct experiences of interacting with *Cinchona* plants, the informants' roles during the operational period of the *Cinchona* plantation, as well as the memories and emotions associated with the plant. The resulting codes were subsequently analyzed qualitatively and processed into narrative form through data triangulation involving cross-checking and synthesizing.

RESULTS AND DISCUSSION

Ethnobotanical memory in a post-plantation landscape

In recent academic discourse, the concept of botanical memory has emerged, integrating various theoretical frameworks including collective memory, sensory memory, and bodily memory. Botanical memory refers to a form of recollection that combines emotionality, sensuousness, and embodiment, manifested through inner imagery and reminiscence of plant life. The plant can be existed in the past or that currently exists but evokes past events or landscapes (Ryan 2013, 2017; Lugo-Morin 2022). This memory is not limited to individual recollection but extends to entire human communities who were or are exposed to specific flora. This aligns with the concept of collective memory which emphasizes individual memories shared by members of a community who have undergone similar experiences (Assmann and Czaplicka 1995; Linke 2001; Ryan 2013, 2017; Damanik 2020; Rosalina and Zuhdi 2020).

Botanical memory involves emotional recall, where certain plants elicit feelings of nostalgia or mourning, particularly in the context of biodiversity loss when compared with past environmental conditions. It also involves sensory memory, activated through vision, hearing, smell, taste, or touch and manifesting in recollections of a plant's color, aroma, flavor, and texture. It also encompasses bodily memory, such as the recollection of gestures like flower picking or nectar sucking (Ryan 2013, 2017). When combined with ethnobotanical approaches which emphasize local

knowledge and spatial embeddedness (Folke 2004; Hurrell and Albuquerque 2012; Anderson 2017), the concept of ethnobotanical memory emerges. Therefore, ethnobotanical memory can be defined as the collective memory of a community concerning the local knowledge and use of specific plants, expressed through sensory perception, bodily gestures, and emotional associations.

One of the key conditions for the formation of ethnobotanical memory is the transformation of biodiversity, such as the disappearance of a particular species. In the case of this study, ethnobotanical memory is held by the local residents of a former plantation area. For over a century, the community—predominantly composed of plantation laborers—was exposed to *Cinchona*, cultivated as a plantation commodity. Following the closure of the *Cinchona* plantation in 1998, this area experienced a land use transformation to upland agriculture, resulted in the massive decrease of *Cinchona* population. In the past, nearly the entire village landscape was covered by *Cinchona* forests, which today can only be found in small numbers in remote areas far from residential settlements. These circumstances have enabled the emergence of post-plantation landscape; wherein former plantation areas have undergone land-use transformations. This phenomenon does not seem to affect all plantation commodities, but rather only certain species deemed no longer commercially viable, due to declining market demand or shifts in political-economic policy (van der Hoogte and Pieters 2014; Ku 2016; Damanik 2020; Nuralia and Imadudin 2021; Li 2024). Such was the case with *Cinchona* and coca (*Erythroxylum novogranatense* (Morris) Hieron.) which once dominated Dutch East Indies plantation landscapes but experienced significant decline in the post-independence era (Bosman 2012; van der Hoogte and Pieters 2013). In post-plantation landscapes like these, commodity plant species may either disappear entirely, experience a drastic population decline leaving only a few remnants, or become escapees that grow wild. The species often going unrecognized by the local residents.

Meanwhile, studies on plantations have often emphasized the institution as a hegemonic and extractive force, comparable to military occupation (Li and Semedi 2022). It is frequently oppressing labor through mechanisms of control designed to ensure a continuous workforce, often maintained via intergenerational recruitment and paternalistic welfare regimes under the New Order and beyond (Barral 2012, 2014; Gibbon et al. 2014; Li 2017a, b, 2024). In the colonial period, this also involved physical boundaries and punishments imposed on workers (Stoler 1985; Breman 1989, 2015). While plantation studies have extensively explored political-economic dynamics, they have often neglected the relationship between human and the botanical commodities around them. This research addresses that gap by highlighting the residual ethnobotanical memory held by local residents of a post-plantation area, regarding a once-dominant plantation commodity that has since disappeared due to shifts in local land use.

Therefore, the following section will describe the ethnobotanical memory held by local residents of the village as part of a post-plantation landscape. The section begins by discussing local terminologies related to *Cinchona*, followed by three additional memory narratives. The categorization of these narratives draws on the concept of botanical memory as a combination of emotional, bodily, and sensory memory (Ryan 2013, 2017). These three narratives represent practices that took place in the past and now exist only as memories. In other words, the cultural practices associated with them are no longer carried out in the present. The following is a detailed explanation.

Local terminologies regarding *Cinchona*

The *Cinchona* genus cultivated at the study area consisted primarily of two species: *Cinchona pubescens* Vahl (Figure 3) and *C. calisaya* (Figure 4), each serving distinct roles. Their introduction to the plantation was part of broader trajectory of imperial botanical advancement that began in 1865, when Charles Ledger brought *Cinchona* specimens from Bolivia that was later classified as *C. calisaya* (syn. *C. ledgeriana*). This species was subsequently cultivated by the Dutch colonial government on plantations in the Malabar highlands, Preanger West Java. In 1872, small quantities of its bark were auctioned in Amsterdam, fetching higher prices than other *Cinchona* products sourced from Java, Sri Lanka, or India due to its quinine content exceeding 5% (Gorkom 1883; Cuvi 2011; Goss 2014; van der Hoogte and Pieters 2014).

Despite its high alkaloid concentration, *C. calisaya* had weak root systems and could only thrive in recently cleared primary forests. To address this, colonial scientists developed grafting techniques that combined *C. calisaya* as the scion with *C. pubescens* (syn. *C. succirubra*), a species known for its strong root systems as the understock. The resulting hybrid retained the high quinine content and the robust rooting capacity in the new individual (Gorkom 1883; Sukasmono 1995; Maxiselly et al. 2018).

This propagation method became widely adopted across *Cinchona* plantations in Java, including in this study area. As a result, both species remain etched in the local population's memory, as reflected in their use of specific local terminologies. *Cinchona pubescens* (syn. *C. succirubra*), the rootstock species, is locally referred to as '*sulibra'* or '*subsirubra'* (Figure 3), terms derived through phonetic metathesis from its Latin name. Meanwhile, *C. calisaya* is more broadly referred to as '*kina'* (Figure 4). The term *kina* also refers to the grafted hybrid individuals produced from both species, which means this term carries a dual meaning (Table 1).

Emotional memory: *Cinchona* and nostalgia of childhood

The concept of ethnobotanical memory allows a collective community to retain memories of specific plants that have been continuously present in their daily lives. These plant-related memories can take the form of emotional memory, which means memory that evoke certain emotional responses (Ryan 2013, 2017). In the context of this study, emotional memory of *Cinchona* is

evident in the sense of nostalgia that arises during the process of recalling the plant.

Local residents born in the 1970s and 1980s often associate *Cinchona* with their childhood years. Many recall spending their afternoons playing within the boundaries of the plantation, a restricted area that was off-limits to unauthorized individuals. The plantation's processing facilities and administrative buildings were strictly reserved for authorized personnel, such as workers and laborers. This spatial exclusivity effectively excluded local inhabitants who did not rely on plantation labor for their livelihoods, creating a distinct social boundary between plantation-affiliated and non-affiliated communities.

This exclusivity was maintained through regular security patrols by plantation guards, who monitored the area to prevent trespassing and potential crime. These patrols, in turn, became part of the collective memory of childhood for those who grew up near the plantation. Children, most in their early teens or younger, often spent their afternoons playing around the *Cinchona* field, until they were either called home by the evening *adhan* (Muslim call to prayer) or chased away by security guards for entering restricted zones. The presence of these guards added an element of excitement to their games, intensifying the thrill of the childhood experience (Table 1).

Nostalgic memories of *Cinchona* also refer to the physical presence of the tree itself. Residents vividly recall the tall perimeter fence surrounding the processing plant, constructed entirely from debarked *Cinchona* trunks. These imposing wooden posts, nearly matching the height of the processing facility, reflected the substantial size of *Cinchona* trees at the time, estimated to have reached 10 to 15 meters in height. Thus, botanical memory in this context is more than an emotional attachment; it also functions as a recollection of botanical scale and material use, where trees once cultivated for their bark became structural elements in the landscape.

The memory of childhood games in restricted plantation areas also reflects the broader social exclusivity embedded within plantation society. At the time, plantation workers were often perceived as living somewhat separate, even elite, lives compared to their non-plantation neighbors. This perceived exclusivity was, in part, an outcome of the plantation institution's role as an agent of economic development in frontier regions (Li and Semedi 2022), fostering a sense of occupational pride among plantation workers. However, it was also shaped by the paternalistic structure of plantation governance, which offered selective welfare benefits in exchange for compliance and labor continuity (Barral 2012, 2014; Gibbon et al. 2014). Such policies entrenched the exclusivity of plantation life, fostering distance—both literal and symbolic—between plantation laborers and non-affiliated villagers. These dynamics make clear that botanical memory, especially in the case of *Cinchona*, extends beyond the species itself. It encompasses emotional sentiments, nostalgic reflections, and the broader social and political conditions surrounding the plant's cultivation. In short, memories of *Cinchona* serve as an entry point into understanding the lived experiences of plantation life and the lingering residues of institutional control within a post-plantation society.

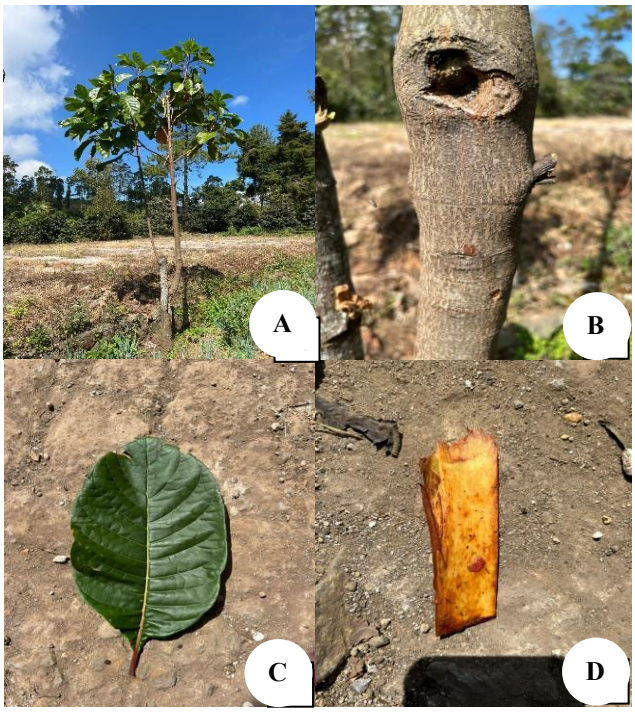

Figure 3. The escapee of *Cinchona pubescens* Vahl (red bark), consists of: A. Tree, B. Trunk, C. Leaf, and D. Bark

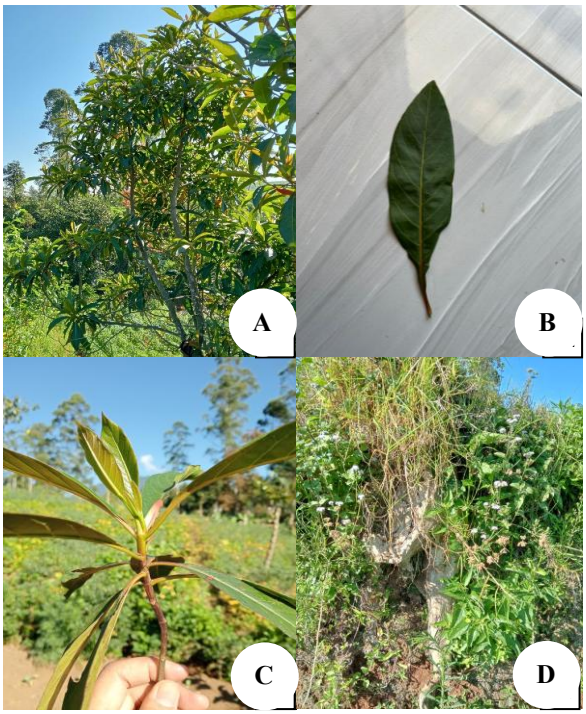

Figure 4. *Cinchona calisaya* Wedd. (yellow bark), consists of: A. Tree, B. Leaf, C. Shoot, and D. Understock resulting from grafting with *Cinchona pubescens* Vahl.

Bodily memory: plantation production stages of *Cinchona*

Ethnobotanical memory also manifests as bodily memory, referring to recollections of events that are closely tied to physical movements (Ryan 2013, 2017). In the context of this study, bodily memory of *Cinchona* emerges through memories of the plantation production stages before being sent to the pharmaceutical factory in Bandung City, for processing into malaria medication. These memories are generally held only by former workers of the plantation and are often recounted alongside physical gestures, especially when describing certain stages of the process. Below is a detailed description of each stage of *Cinchona* production in study area, supported by photographic documentation obtained from Dutch archival sources.

The plantation production stages of *Cinchona* were divided into seven distinct phases (Figure 5). First was the selection of *C. pubescens* seeds. The seed selection process was carried out using chicken feathers due to its small size, which required fine and delicate materials. Viable seeds were identified by their perfectly round shape and brownish-green color. In this stage, patience and manual dexterity in separating each individual seed were essential. The second stage involved sowing the seeds in a designated area known as *ikupan* or *bedengan* (covered seedbed in Sundanese). Seedlings were initially grown to approximately 10 cm in height, after which they were transplanted into new nursery beds and cultivated until they reached 40-50 cm. This process could take up to four years.

Third, the stage of grafting or *stek sambung*. A small patch of bark from *C. pubescens* was carefully peeled away, then grafted with a shoot from *C. calisaya*. The two were bound together using melted wax and bamboo twine. Occasionally, plastic bags were used for binding, though less frequently due to concerns about suffocation. After 3-4 months post-grafting, new shoots would emerge. This marked the transformation into what was locally recognized as a true *kina* tree, a fusion of *C. pubescens* rootstock and a *C. calisaya* scion. Fourth was bark-stripping, the primary objective of cultivation, as the bark of the *kina* tree—harvested from both trunk and branches—contained high concentrations of quinine (Gorkom 1883; Goss 2014; Gachelin et al. 2017; Maldonado et al. 2017). Trees were typically ready for harvest after 6 to 15 years. Workers employed a method called *pekprek* or *mekprek*, striking the bark with a blunt wooden tool until it produced a *"prek!"* sound, allowing it to be peeled off, an action rooted in embodied, bodily memory. Alternatively, a finer quality bark was extracted using sharp tools, though this method was more labor-intensive. Stripped trunks and branches were repurposed as firewood for *belong* (smoking kilns), building materials for workers' housing, and fencing around processing areas.

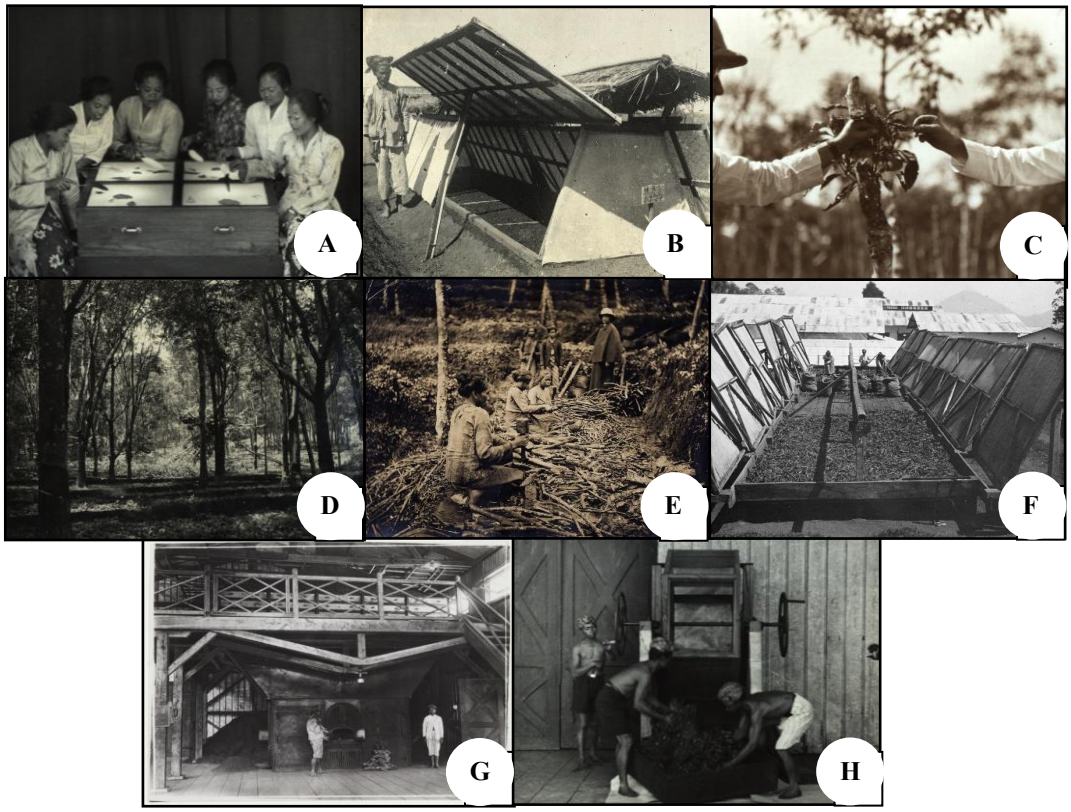

Figure 5. Steps of *Cinchona* production. A. Selection of seeds suitable for planting using chicken feathers (KITLV 408739), B. Seed germination in beddings called *ikupan* (KITLV 408831), C. Grafting cuttings (KITLV 408543), D. Mature trees ready for harvest (KITLV 408459), E. Peeling bark from its trunk and branch using a method called *pekprek* (KITLV 183810), F. Sun-drying the barks on rack named *paratag* (KITLV 500358), G. Smoking the dried bark in a chamber called *belong* (KITLV 34637), and H. Bark grinding into powder form (KITLV 408753)

Fifth was sun-drying the bark, placed on a tray-like structure with an iron frame and two zinc roofs, locally known as *paratag*. The drying process typically lasting one to two weeks, depending on weather conditions. When it rained or during the night, the zinc sheets were repositioned to cover the bark. The term *paratag* may derive from *parat*, which in Sundanese means "to have a through-passage". The word also appears in the expression *liang parat*, meaning a tunnel or an open channel with a clear passage from one end to the other (Rigg 1862), resembling the structure formed by the zinc sheets when closed over the platform. In contemporary Sundanese, *parat* can also mean "to pass through", "until it's finished", or "to completion".

Sixth was bark-smoking. Once adequately sun-dried, the bark was moved from *paratag* to *belong*, a type of furnace used to smoke the bark. The purpose was to make the bark easier to grind during the milling stage. The bark was placed on trays in the upper chamber of the furnace and smoked until its texture changed. The firewood used in the *belong* often came from the stripped trunks or branches of the *kina* tree. Finally, the milling process transformed the dried bark into powder. The smoked bark was transferred to a grinding machine, and in some cases, ground together with rice grains. The resulting product was referred to as *tepung kina* (*Cinchona* flour). This flour was packed into sacks (*bal)* and delivered to the manufacturing factory in Bandung City (formerly the *Bandung Kininschefabriek* before nationalization), where it was processed into quinine pills used for antimalarial treatment. The description of memories related to the plantation production stages is often conveyed through a series of body gestures by the informants (Table 1).

Sensory memory: Local consumption of bitter *Cinchona* for medicinal purpose

Ethnobotanical memory also appears as sensory memory, refers to recollections tied closely to the senses (Ryan 2013, 2017). In the context of this study, sensory memory is expressed through the bitter taste detected by the sense of taste during the traditional practice of consuming *Cinchona* decoctions for medicinal purposes, a practice that is no longer carried out today. The laborers had the habit of secretly taking the bark that was being dried on *paratag*, bringing it home, then brewing it. This brew was then consumed with the purpose of curing all kinds of diseases, from fever, chills, itching, to internal diseases. However, when asked what type of internal disease was meant, each informant seemed confused in answering. This multifunctional brew was consumed approximately one glass, once or twice until the body felt more vigorous and taste extremely bitter. Informants often times described it as the most bitter solution ever consumed during their lifetime, leaving a clear trace in the mouth cavity and throat, often caused nausea afterward. Therefore, to rinse away this bitter taste, residents were accustomed to drinking palm sugar solution water (Table 1).

The story about how bitter the solution tasted seemed quite reasonable and not exaggerated, considering that quinine-type alkaloids serve as a standard reference commonly used in expressing a bitter taste (Mahomoodally and Ramalingum 2015). The tendency of local communities to utilize bitter plants for medicinal benefits is also occurs in various places and groups, for instance among traditional societies like the Inga Indians (Zuluaga 2024), Pakistani migrants in England (Pieroni et al. 2008), or rural people in Italy (Pieroni 2001). Local utilization of bitter plants for medicinal purposes is a relatively new matter in the physiology of taste science. Living beings have a genetic predisposition to identify bitter taste from food (including plants) as toxins or decaying food, so there is a tendency to refuse consuming them (Behrens et al. 2018; Zuluaga 2024). Nevertheless, over time through trial-and-error efforts, human realized that not all bitter foods are poisonous, thus including them in their diet menu. Tolerance for bitter taste from consumed plants can be highly adaptive, depending on the consumers. If a community is continuously exposed to a particular plant, then their tolerance level for unpleasant tastes will be higher (Glendinning 1994; Kurihara et al. 1994; de Medeiros et al. 2015). Something similar occurs in the study area, where plantation laborers who are daily exposed to *Cinchona* are used to consume them for health benefits regardless of their prominent bitter taste, which instead becomes sensory memory.

Cases like this seem quite common within plantation contexts and can also be interpreted as a form of resistance effort by lower classes in obtaining benefits from plantation systems that quite suffocate them (Li and Semedi 2022). This *Cinchona* bark taking was done without asking permission from superiors. This 'stealing' behavior occurred at all times but was only found among field laborers and foremen. Meanwhile, positions above them with relatively more decent living standards did not recognize this habit. Similar practices were also carried out in Java and Kalimantan plantations since colonial times, for instance reflected through the habit of stealing coffee leaves to be brewed and enjoyed by laborers (Breman 2015; Li and Semedi 2022).

To facilitate the explanation of the ethnobotanical memory narratives of local residents in the study area regarding *Cinchona*, the following table provides summary of the findings (Table 1). The ethnobotanical memory narratives of *Cinchona* in the study area need to be understood within the context of a combination of emotional, bodily, and sensory memory, held by individuals within a community who share a common experience (Assmann and Czaplicka 1995; Linke 2001; Ryan 2013, 2017; Damanik 2020; Rosalina and Zuhdi 2020; Lugo-Morin 2022). These three types of memory can be observed in this study and compared with findings from similar research.

Table 1. Memory narratives, the remembering subject, and its descriptions regarding *Cinchona*

Memory narratives	Subject	Summary
Local terminologies regarding *Cinchona*	The majority of local residents, across various age groups, both those who have and have not lived in direct proximity to the *Cinchona* plantation during its operational period share this experience. Example: "Sulibra *or* subsirubra *is different from* kina. Sulibra *is the understock, and it's grafted with* kina. *The resulting hybrid is also named* kina." -DK, 60 years old, current senior plantation foreman. "Subsirubra *and* kina *is different. They're distinct types of trees.*" -CW, 29 years old, farmer.	*C. pubescens* (syn. *C. succirubra)* is referred to as '*sulibra'* or '*subsirubra'*. *C. calisaya* is referred to as '*kina'*. The term *kina* is also used to refer to grafted individuals from both species.
Emotional memory: *Cinchona* and nostalgia for childhood	Residents aged between 30 and 82 years who once lived in direct proximity to the *Cinchona* plantation. Example: "*We used to play almost every day in the* Cinchona *field. Actually, we weren't allowed to, because there was a security guard who patrolled regularly. But that made it even more exciting as a child."* -US, 39 years old, teacher. *"We'd turn the* Cinchona *branches into toy weapons, pretending they were guns."* -IO, 45 years old, farmer. *"There was a fence made from* Cinchona *trunks in front of the factory. Each section of the fence came from just one tree, not joined together. And they were really tall, probably over 10 meters."* -IS, 41 years old, farmer.	Evokes feelings of nostalgia and longing for childhood, indicated by childhood habits of playing around and the estimation of the tree size.
Bodily memory: plantation production stages of *Cinchona*	Generally, from the category of former *Cinchona* plantation workers. Example: "*The job of* mekprek *would often make your arms sore, because you had to keep hitting the bark repeatedly. Sometimes, the bark was also hard to peel off."* -NK, 77 years old, former plantation laborer. "*I remember when selecting* sulibra *seeds, we had to be very careful. But once your hands got used to it, you could separate the seeds quickly."* -MJ, 79 years old, former plantation laborer. *"Why is it called* pekprek? *Because the movement kept making a '*prek!*' sound over and over."* -AM, 73 years old, former plantation foreman.	The production stages begin with the selection of the seeds, followed by grafting, harvesting, and processing until becomes powder form.
Sensory memory: local consumption of *Cinchona* for medicinal purpose	Generally, from the category of former plantation workers, particularly low-ranking laborers who worked in the field. Example: *"When* Cinchona *bark is brewed, its benefits can treat nearly every illness. If you have a fever, drink it. If your body aches, chest hurts, even itching, it can cure them. Just drink one glass, maybe twice, and the fever usually goes away immediately."* -JB, 74 years old, former plantation laborer. *"We'd drink a palm or white sugar solution after consuming* Cinchona. *But palm sugar had a stronger taste, so it helped get rid of the bitterness better."* -MT, 70 years old, former plantation laborer. *"We used to secretly take the bark from* paratag *while it was being sun-dried. We only took a little, so it didn't cause any real loss to the plantation."* -EM, 79 years old, former plantation laborer.	Decoctions made from *Cinchona* bark were consumed to treat various diseases.

First, emotional memory in this study is evident in nostalgic sentiments and longing for childhood. Such nostalgia is similarly observed in the study of Ryan (2013), in which grief for the past arises from the extinction of shrub species in Perth, Australia and those experienced by Aboriginal people upon witnessing the disappearance of native vegetation including their totems. In memories of plants consumed during famine years, trauma and sorrow dominate the emotional landscape of survivors (Vorstenbosch et al. 2017; Rosalina and Zuhdi 2020; Ruiz 2024). However, this kind of sorrow is not commonly found in this study. The absence of sorrow over the extinction of *Cinchona* may be attributed to the transformation in land use that took place. It enabled residents to privately manage their own land through household-scale vegetable farming, rather than working solely as wage laborers under the dominant agrarian structure of the plantation.

Second, bodily memory in this study is revealed through memory narratives related to the plantation production stages of *Cinchona*. One such example is the physical demonstration by informants of the *pekprek* stage. This strong presence of bodily memory is also found in other studies, such as Archambault (2016) on backyard gardening routines among working class youth in Mozambique. This also evident in Ryan (2013) on childhood practices of sucking nectar from *Banksia* flowers using gestures like squeezing, chewing, and sucking. These comparisons show that bodily memory among local residents related to *Cinchona* is confined to production activities serving the economic interests of the plantation institution.

Third, sensory memory is found in the local consumption for medicinal purposes. The sense of taste plays a dominant role, as residents describe the decoction as the most bitter liquid they have ever consumed. It is said to linger in the throat, producing an unpleasant aftertaste that must be washed down with a solution of palm sugar. Similar forms of sensory memory appear in other studies. For example, the sweet taste of red drip from *marri* trees (*Corymbia calophylla* (Lindl.) K.D.Hill & L.A.S.Johnson) that gradually turns bitter (Ryan 2017), or the visual cue of overgrown grass in home yards signalling neglect in Detroit neighborhoods (Chenoweth 2017). It also evident in the scent of *khakibos* (*Tagetes minuta*), resembling mentholated ointment well known among Rastafarians in Matzikama, South Africa (Ellis 2018), the ripening of *chanar* fruit (*Geoffroea decorticans* (Gillies ex Hook. & Arn.) Burkart) marked by the chirping of shiny cowbirds (*Molothrus bonariensis* (Gmelin, 1789)) in Bolivia (Sugiyama et al. 2020), the garlic-like scent of *Banksia* flowers (Ryan 2013), the comforting smell of lavender that evokes memories of home and family (Ryan 2017), and the snapping sound of witch hazel (*Hamamelis virginiana* L.) (Walls 2017).

In addition to comparing the three types of memory, this study also needs to be contextualized within the broader body of research on *Cinchona*. It is difficult to find studies that apply a memory framework to the species. Typically, *Cinchona* is examined through the lens of local knowledge concerning its consumption, medicinal use, and cultivation methods (Philip 1995; Chakrabarti 2010; Crawford 2010, 2021; Júnior et al. 2012; Gachelin et al. 2017; Jäger 2018; Mekonnen et al. 2025; Rodriguez 2025). For example, in the precolonial period, *Cinchona* was reportedly widely used by native healers in the Andean regions as a medicinal plant, and by indigenous peoples as a remedy for shivering caused by exposure to humidity and cold (Philip 1995; Crawford 2010, 2021; Júnior et al. 2012; Gachelin et al. 2017; Jäger 2018). In Brazil, the identification of plants referred to as "*quina*" is done their distinct bitterness, and includes species from another genus such as *Solanum pseudoquina* A.St.-Hil. (*quina do Piauhy*) and *Strychnos pseudoquina* A.St.-Hil. (*quina do campo*) and used for medicinal purposes (Cosenza et al. 2013; Rodriguez 2025). A similar tendency can also be seen in the Rajahmundry region of India, where *Soymida febrifuga* (Roxb.) A.Juss. is used locally as a febrifuge and remedy for stomach ailments (Chakrabarti 2010). In addition, the plant was once explored as a potential remedy for COVID-19, a discourse also presents in the context of *Cinchona* plantations in Darjeeling, India (Middleton 2019, 2021, 2024).

From this body of literature on *Cinchona*, it is evident that studies employing an ethnobotanical memory framework are rare. Most rely on a local knowledge approach, emphasizing how communities understand and engage with plants in ways that are bounded to their local context (Crawford 2010, 2021; Júnior et al. 2012; Jäger 2018). Even so, there is potential overlap between the frameworks of local knowledge and ethnobotanical memory. As demonstrated in this study, the ethnobotanical memory of *Cinchona* contains elements of local knowledge, such as its uses and production stages. However, prior studies on local knowledge have not examined *Cinchona* as a former colonial plantation commodity situated within a landscape that has undergone land-use transformation.

In this research, each memory narrative identified can only emerge from the political-economic conditions that enabled the presence of *Cinchona* plantations in Indonesia. It is rooted in colonial and imperial histories, as well as scientific developments in botany during the late 19th to 20th centuries to serve demand for anti-malarial medicine. In sum, human memory of a particular plant species must be situated within broader global socio-economic contexts. This study offers a novel contribution by mapping the distribution of memory related to *Cinchona*. That distribution is reflected in the minimal intergenerational transmission of memory regarding the species. This is largely a result of the normalization of land use transformation as will be discussed in the following section.

Land use transformation and the absence of conservational efforts of *Cinchona*

The ethnobotanical memory narratives above are recollection of the past and no longer practiced today. This happened due to land-use transformation that have led to the decreasing population of *Cinchona.* Furthermore,

conservation efforts for this plant remain very limited, one of which is reflected in the existence of the '*Musium Kina*,' meaning the Museum of *Cinchona* (Figure 6). *Museum Kina* serves as a physical monument that deliberately records the once-thriving *Cinchona* plantation, also functions as a landmark that serves as a gateway to the village. This landmark features a stretch of vegetable gardens with raised lettering spelling out "TJIKEMBANG", situated to the left of the road from northern part, and serves as a welcome sign. Amidst the garden, several tall, leafless *Cinchona* trees stand prominently. This monument was originally established by plantation authorities in the 1980s as a public park and was intended to conserve *Cinchona* species despite the closure of the plantation. Nevertheless, this conservation effort can be considered a failure, as the tree population has continued to decline due to the interests of land authorities. In May 2024, there were 10-15 trees, which then decreased to only 2 individuals by August 2024.

The absence of *Cinchona* conservation efforts is related to local land-use preferences. *Cinchona* is considered less profitable to cultivate individually. The reason is that this plant requires a long time before it can be harvested, up to 10 years. This botanical characteristic makes it less profitable compared to vegetables, which can be harvested twice a year. In addition, the absence of middlemen outside the plantation system also made it difficult for local residents to market the cultivation of *Cinchona* grown individually. This situation is somewhat different from other plantation commodities, such as tea, which can be planted on privately owned land due to the availability of alternative middlemen outside plantation institutions.

Therefore, the failure of conservation efforts can be attributed to several factors. *Cinchona* is a Neotropical species that was introduced as a commodity for imperialism. When global demand declines, a plant can lose its commercial value, as happened with *Cinchona* after World War II. In addition, population pressure on land has also been an influential factor. This allowed local communities to shift land use from *Cinchona* plantations to subtropical vegetable farming (Mulyanto 2022). The transformation was shaped by broader political climate of the time, which encouraged widespread land occupations across Java and Sumatra as a reaction to the unfulfilled agrarian reform during the New Order regime (Bachriadi and Lucas 2001; McCarthy and Robinson 2016). This land use transformation was also driven by the 1970s Green Revolution which provided synthetic fertilizer and pesticide supplies to highland farmers, enabling the practice of upland agriculture (Mulyanto 2022). The provision of Agricultural Business Credit (*Kredit Usaha Tani*) in the early 2000s also provided start-up capital for new farmers. This lack of conservation effort contrasts with other regions, such as China and Kenya, where bio-cultural heritage landscapes have successfully integrated tourism, local customs, and livelihood systems (Su et al. 2016a, b, 2018; Ekblom et al. 2019).

On decreasing *Cinchona* population and the loss of ethnobotanical memory

The absence of conservation efforts for *Cinchona* species in study area has led to the loss of ethnobotanical memory. In this context, knowledge and memory of *Cinchona* are generally retained only by those who directly lived alongside the *Cinchona* plantation during its active period. Such memory is not transmitted to their younger generations, such as children and grandchildren. The distribution of this ethnobotanical memory can be seen in the diagram (Figure 7).

Residents under the age of 30, who have never lived in direct proximity to *Cinchona* plantations, tend to know only the general terms of '*kina,*' '*sulibra*,' or '*subsirubra*.' Beyond that, they possess no knowledge related to *Cinchona* due to the absence of intergenerational transmission. This tendency is evident in their inability to recognize the plant itself. Some even stated that all of it had completely disappeared from the village, without recognizing the remaining *Cinchona* trees in the area of *Museum Kina*. This inability to recognize the species is also accompanied by a lack of knowledge about the cultural practices surrounding it, such as plantation production stages and local consumption for medicinal purposes.

This loss of memory occurred due to the decreasing population of *Cinchona* as a result of land use transformation. The landscape that was once filled with *Cinchona* has undergone significant clearing. The decreasing population of this species has led to the disappearance of related activities, from production to local medicinal use of the plant. Eventually, along with growing insecurity related to land tenure, the memory of those cultural practices continues to fade. At present, although the land is occupied by farmers, its legal rights still fall under plantation leasehold. In other words, preserving memory of the *Cinchona* among the village residents is tantamount to recalling the vulnerability of the land that underpins their livelihoods.

Figure 6. Neglected *Musium Kina* in Cikembang Village, Kertasari Sub-district, Bandung District, West Java, Indonesia

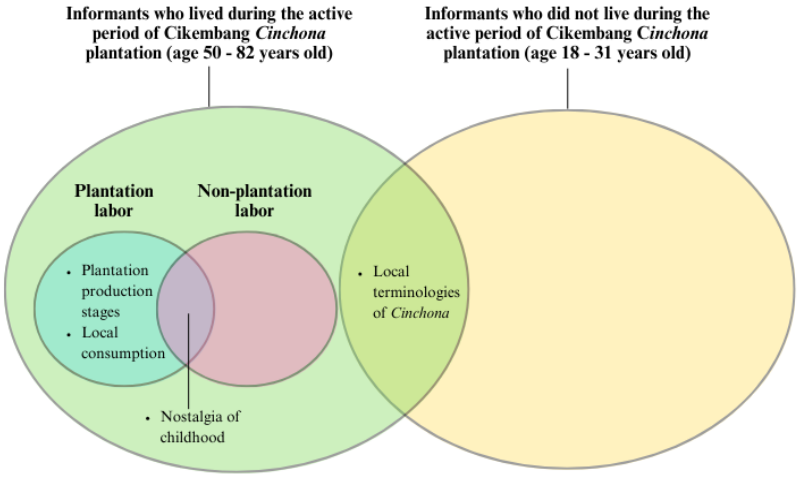

Figure 7. A diagram illustrating the relationship between informant categories and ethnobotanical memory narratives

This condition illustrates the co-evolution between biological and cultural aspects, forming a complex adaptive system as reflected in the concept of bio-cultural diversity. There exists interdependence linking plant and animal species together with their habitats and ecosystems (biological diversity), as well as various types of human cultures and languages (cultural and linguistic diversity) (Harmon 1996; Dressler 2005; Maffi 2007, 2018; Agnoletti and Rotherham 2015; Amici et al. 2015). The close connection between biological and cultural diversity is commonly observed in rural areas, based on the assumption that rural communities live in a more 'traditional' and 'nature-bound' manner (Agnoletti and Rotherham 2015). In relation to this, land use becomes a crucial factor in determining the existence of biological species, which then co-evolve with the cultural practices of surrounding human populations (Amici et al. 2015). This bio-cultural diversity perspective is clearly applicable to the phenomenon of the loss of ethnobotanical memory associated with *Cinchona* occurring in study area due to the decreasing species population. The interdependence is clearly evident when the plantation ceased operations, seen in the loss of ethnobotanical memory among the younger generation of local residents.

Another important point to note concerns the testimonies of individuals. oftentimes, they do not realize that the memory and knowledge of *Cinchona* are undergoing a process of forgetting within their own community. However, this impression can be obtained through the researchers' own analysis, a tendency commonly observed in studies related to memory and local knowledge. This implies that researchers need to be more attentive in uncovering and analyzing the underlying meanings.

In conclusion, ethnobotanical memory related to *Cinchona* can be gleaned from the testimonies of local residents in the study area as a post-plantation landscape. The memory narratives include local botanical terminology, sentiments of childhood nostalgia, plantation production stages, and local consumption for medicinal purposes. These memory narratives surrounding *Cinchona* illustrate how human cultural interactions and the presence of the species in the village were once closely intertwined, but have gradually faded over time. The fading of this ethnobotanical memory is primarily due to the absence of conservation efforts for the species, driven by several factors such as the collapse of the *Cinchona* bark market, population pressure, and land-use transformation. This led the interdependence of biological species, cultural practices, and linguistic expressions. Both memory and practice related to *Cinchona* have likewise been undergoing a process of erasure. This may represent a strategic adjustment in sustaining current livelihood strategies as vegetable farmers whose land remains part of the former plantation concession and who face the risk of eviction at any time. In other words, the presence of biological species and cultural activities (in this case, memory) are deeply interconnected and influenced by the broader national political-economic context. Thus, the story of a plant is not merely about sentiment or nostalgia, it also reflects the wider political-economic structures that shape it.

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Ritual plant diversity and traditional knowledge in the Aneuk Jamee Tribe, Aceh, Indonesia

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Abstract. *Saudah, Rubiah, Zumaidar, Fitriyana L. 2025. Ritual plant diversity and traditional knowledge in the Aneuk Jamee Tribe, Aceh, Indonesia. Asian J Ethnobiol 8: 347-366.* Ritual plants are essential in maintaining biocultural identity among indigenous communities. However, traditional knowledge related to ritual plant use is under threat from modernization and remains poorly documented. This study aimed to systematically document the diversity of ritual plants, analyze their cultural significance, and assess their conservation relevance among the Aneuk Jamee Tribe in South Aceh, Indonesia. Ethnobotanical data were collected through semi-structured interviews with 100 key informants selected via purposive snowball sampling. Use Value (UV), Relative Frequency of Citation (RFC), and Index of Cultural Significance (ICS) were calculated to quantify the importance of each species. A total of 78 plant taxa belonging to 42 families were identified, with Poaceae being the most represented family (10 taxa). Two additional names were recognized as synonyms and therefore not counted as separate taxa. Herbaceous plants dominated (43.2%), and most species (77.2%) were cultivated, mainly in home gardens. *Oryza sativa* var. *glutinosa* (UV=0.86; RFC=0.86; ICS=179.5), *Piper betle* (UV=1.47; RFC=0.51; ICS=179.5), and *Cocos nucifera* (UV=1.54; RFC=0.76; ICS=179.5) emerged as the top three species, functioning as cultural keystone plants. These plants are used in various rituals, including weddings, births, circumcisions, agricultural rites, and mystical ceremonies. Findings emphasize the deep cultural embeddedness of ritual plant use and the urgent need to safeguard this knowledge. Home gardens serve as reservoirs of culturally significant plants, and engaging younger generations is vital for transmission and conservation.

Keywords: Aneuk Jamee Tribe, biocultural conservation, ritual plant diversity, South Aceh, traditional knowledge

Abbreviations: ICS: Index of Cultural Significance, RFC: Relative Frequency of Citation, UV: Use Value

INTRODUCTION

Indonesia is renowned for its remarkable cultural diversity, where traditions are often expressed through ritual practices (Mailin et al. 2023). Rituals are symbolic activities performed in specific sequences, that carry deep spiritual and cultural meaning (Kapoor et al. 2022). They serve as a medium for communities to connect with their ancestors, the natural world, and the divine. Within these traditions, plants play a central role, representing both the symbolic relationship between humans and nature and the unique cultural wisdom of each ethnic group (Hakim 2014; Teixidor-Toneu et al. 2018; Chaachouay et al. 2021; Bria et al. 2023).

Ritual plants function is not only as symbolic and spiritual elements, but also as resources valued for their medicinal, ecological, and ethnopharmacological importance (Chaachouay et al. 2021; David et al. 2022; Moricca et al. 2023). They are often believed to influence physical, emotional, and spiritual well-being (Fan 2016; Ma et al. 2024). Their integration into ceremonies highlights their role in strengthening cultural identity and supporting biodiversity conservation (Quiroz et al. 2016). In Indonesia, plants are used spans diverse ceremonies, including weddings, harvest rituals, protective offerings, and healing practices. Yet, rapid modernization and declining intergenerational knowledge transfer threaten the continuity of this tradition (Putri et al. 2017; Navia et al. 2020b; Suwardi et al. 2020a).

Ethnobotanical studies in Aceh and surrounding regions underscore the importance of documenting traditional plant knowledge. Research among the Gayo people revealed extensive use of medicinal and ritual plants linked to ecological management (Iskandar and Iskandar 2017). In South Aceh, Suwardi et al. (2020b) recorded coastal community practices that integrate ritual symbolism and daily plant use. Postpartum traditions in Aceh Besar also demonstrated the significance of medicinal and protective plants for maternal care (Zumaidar et al. 2019a; Nursamsu et al. 2024). Despite these contributions, research has largely concentrated on food security and medicinal uses, with less attention to plants in ritual symbolism. This gap highlights the need to study ritual plants more comprehensively within Aceh's diverse cultural landscape.

One ethnic group that has managed to maintain its traditional practices in Aceh is the Aneuk Jamee Tribe.

The Aneuk Jamee Tribe is located primarily in South Aceh District, such as Tapaktuan, Samadua, Labuhan Haji, and Sawang Districts, with smaller populations in West Aceh, Southwest Aceh, Aceh Singkil, Simelue and Banyak Islands, represents an ethnic group where ritual plant knowledge remains underexplored. Their population, estimated at 74.000-78.000 individuals (±14% of Aceh's population), constitutes nearly 30% of the South Aceh District. Descended from Minangkabau migrants, they have blended Acehnese and Minangkabau traditions into distinctive cultural practices (Wulanda et al. 2021; Sefriyono et al. 2024). While ritual ceremonies remain vibrant, knowledge of plants used is passed down orally and increasingly vulnerable to erosion (Baker et al. 2020; Sutrisno et al. 2020).

The ritual plant knowledge of the Aneuk Jamee Tribe demonstrates sophisticated ecological knowledge shaped by symbolic meaning, medicinal value, and accessibility of species. These practices reflect cultural resilience while contributing to sustainable natural resource use (Nursamsu et al. 2024). This study aimed to systematically document and analyze the diversity, cultural functions, and conservation relevance of ritual plant use by the Aneuk Jamee Community in South Aceh, Indonesia. Specifically, it identifies the plant species used in ritual contexts, explores their symbolic and functional roles, and situates this knowledge within broader ethnobotanical research and biodiversity conservation discourses. By filling a critical gap in Aceh's ethnobotanical research, the study contributes to preserving cultural heritage and reinforcing the role of ritual plants in biodiversity conservation.

MATERIALS AND METHODS

Study area

This research was conducted in Kota Bahagia Sub-district, South Aceh District, Aceh Province, Indonesia. The district is geographically located between 02°23'24"-03°44'24" N and 96°57'36"-97°56'24" E, at an elevation of 0-25 m above sea level (m asl). The climate of Kota Bahagia is classified as humid tropical, with an average annual rainfall of 2,634.5 mm (219.5 mm per month), while more recent records from BPS indicate an average monthly rainfall of 289.5 mm and about 18 rainy days per month. The average daily temperature of 29°C (Mufti et al. 2017; BPS 2024).

The district has an area of 252.6 km² and had a population of 7,460 peoples, consisting of 3,742 males and 3,718 females. Geographically, Kota Bahagia is unique because it lies within the buffer zone of Gunung Leuser National Park, bordered by both extensive coastlines and mountains. This ecological setting provides a rich diversity of flora and fauna, including an abundance of medicinal and ritual plants. Demographically, the Aneuk Jamee Tribe is one of the three major ethnic groups in South Aceh District, alongside Acehnese and Kluet. They constitute approximately 30% of the district's total population (BPS 2024). Although no specific census data exist for the Aneuk Jamee population in Kota Bahagia, field observations and previous ethnobotanical surveys confirm their strong presence in this sub-district. The research was conducted in October 2024, covering four villages within Kota Bahagia Sub-district i.e., Jombo Keupok, Alur Duamas, Ujong Tanoh, and Beutong Villages (Figure 1).

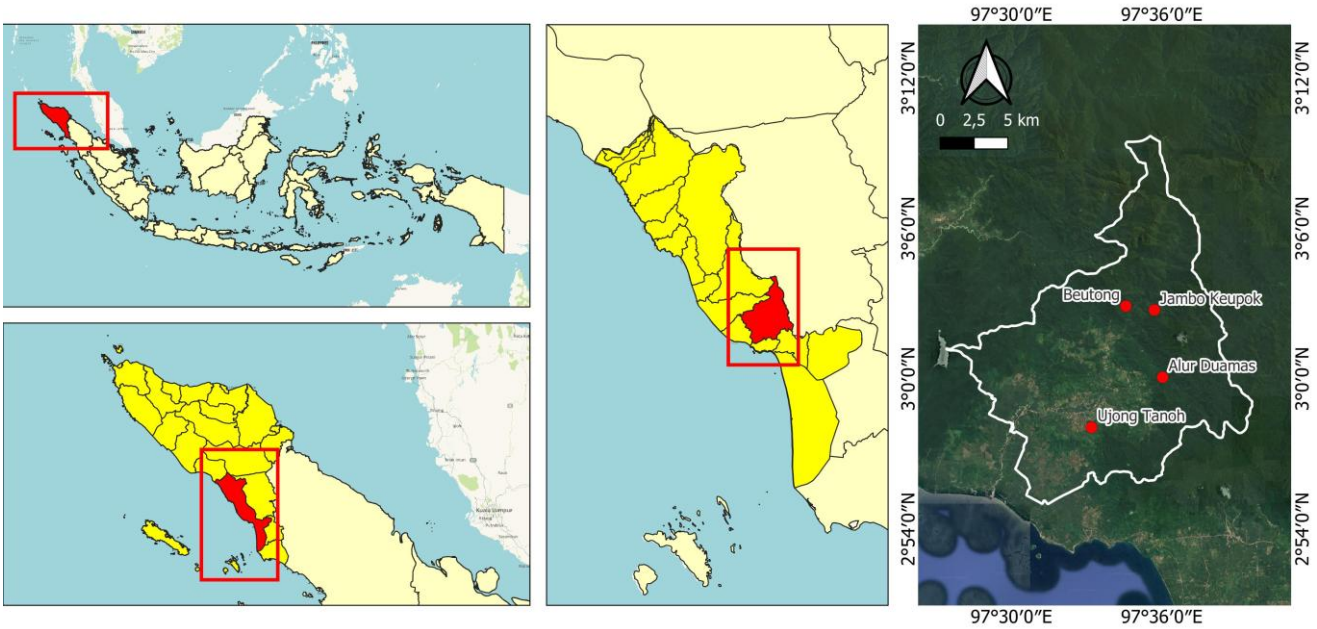

Figure 1. Research sites in Kota Bahagia Sub-district, South Aceh District, Aceh Province, Indonesia

Informant selection

A total of 100 key informants were selected using purposive snowball sampling (Table 1), a technique widely used in ethnobotanical studies (Albuquerque et al. 2014). This method was chosen because ethnobotanical knowledge is often unevenly distributed, typically concentrated among specific social groups or family lineages. Starting with initial key informants, participants were asked to refer other knowledgeable individuals, facilitating access to trust-based, culturally embedded knowledge. Efforts were made to ensure demographic variation across age and gender groups. The majority of informants (74%) were female, reflecting gendered divisions of ritual knowledge and household herbal practices. While this provided rich insights, it may also bias the results toward female-associated uses and underrepresent male ritual domains. Older respondents were more represented, potentially underestimating youth perspectives and emerging changes in ritual plant use.

Data collection

Ethnobotanical data were collected through field surveys and semi-structured interviews. Respondents were asked to identify plant species, provide local names, specify plant parts used, describe ceremonial applications, and explain preparation methods. In addition to functional details, they were encouraged to share oral narratives, symbolic meanings, and cultural associations of each plant, thus capturing intangible heritage and lived experiences (Wang 2023). This approach served as both a scientific tool and a mechanism for cultural preservation, highlighting the role of ritual plants in community identity, social cohesion, and spiritual expression (Lulekal et al. 2014; Espinoza-Pérez et al. 2021).

Plant identification

Plant identification was conducted through a combination of direct fieldwork and herbarium verification. Initial identification relied on local names and uses, supported by photographs and field notes (López-Patiño et al. 2022). Plants were documented through photographs and contextual notes. Specimens with uncertain scientific identity were collected and taxonomically verified at the Herbarium Acehense, Syiah Kuala University. Species names were standardized using the online database Plants of the World Online (POWO 2025).

Data analysis

This study applied both qualitative and quantitative ethnobotanical approaches. Qualitative data form interviews were grouped according to plant type, part used, and ritual function, while quantitative analysis employed three indices: Use Value (UV), Relative Frequency of Citation (RFC), and the Index of Cultural Significance (ICS).

Use Value (UV)

The Use Value quantifies the relative importance of each species, reflecting how frequently a plant is cited by informants (Phillips and Gentry 1993). It was calculated as:

$$UV = U/N$$

Where, U: Number of citations per species, N: Total number of informants. UV values range from 0 (no reported use) upwards, with values >1 indicating highly important and frequently used species. In this study, UV values were categorized as: low (0–0.5), moderate (0.5–1.0), and high (>1.0) (Phillips and Gentry 1993).

Relative Frequency of Citation (RFC)

The Relative Frequency of Citation (RFC) reflects the proportion of informants mentioning a plant species:

$$RFC = FC/N$$

Where, FC: Number of informants citing a species, and N: Total number of informants. RFC values range from 0 to 1; species with values closer to 1 are more popular and widely recognized within the community (Tardio and Pardo-de-Santayana 2008).

Index of Cultural Significance (ICS)

The Index of Cultural Significance (ICS) evaluates the cultural weight of each plant species by integrating aspects of frequency, intensity, usefulness, and exclusivity of use (Turner 1988):

$$ICS = \Sigma (Q \times I \times U \times C)$$

Where, Q: Number of informants citing the species, I: Intensity of use, U: Usefulness, and C: Cultural importance. Higher ICS values identify plants that are not only widely used but also central in ritual symbolism and cultural expression.

Ethical statement

Prior informed consent was obtained from all informants before interviews. Local community leaders approved this study, and data collection followed ethical guidelines for research involving indigenous knowledge.

Table 1. Demographic structure of respondents in Kota Bahagia Sub-district, South Aceh District, Aceh Province, Indonesia

Parameter	Specification	Frequency	Percentage
Gender	Male	26	26
	Female	74	74
Age	15–25	11	11
	26-35	14	14
	36-45	15	15
	46-55	19	19
	56-65	19	19
	>65	22	22
Education	No Schooling	12	12.1
	Elementary School	17	17.2
	Junior High School	28	28.3
	Senior High School	28	28.3
	University	14	14.1

RESULTS AND DISCUSSION

Socio-demographic characteristics

A total of 100 respondents were interviewed in four villages in Kota Bahagia Sub-district, South Aceh District, Aceh Province, Indonesia, consisting of Jambo Keupok, Alur Duamas, Ujong Tanoh, and Beutong with 20 respondents from each village. Of these, 26 were males (26%) and 74 were females (74%) (Figure 2). The predominance of female respondents reflects their central role in managing household rituals, medicinal practices, and their responsiveness during interviews, a pattern also noted in previous ethnobotanical studies in Aceh (Navia et al. 2020a).

Respondents ranged in age from 15 to >65 years (Figure 3), with the largest groups being >65 years (22.2%), 46-55 years (19.2%), and 56-65 years (19.2%). These old age groups were crucial for accessing traditional knowledge, as most information is transmitted orally across generations. In terms of education, the majority had junior secondary (28.3%) and senior secondary (28.3%) education, followed by primary school (17.2%), no schooling (12.1%), and college (14.1%) (Table 1). This variation in educational backgrounds provided a diversity of perspectives, enriching the dataset on ritual plant knowledge.

The demographic profile highlights that older community members, especially female, are the primary custodians of ritual plant knowledge. Their lived experiences and repeated participation in ceremonies enabled them to respond more effectively to interview questions compared to younger groups, whose knowledge is more limited (Sutrisno et al. 2020). These findings echo studies in Laos, Malaysia, and Kalimantan, which show that modernization and formal education often disrupt traditional knowledge systems, leading to a decline in intergenerational transmission (Aswani et al. 2018; Navia et al. 2020a). The age, gender and education distribution of respondents (Figures 2 and 3; Table 1) thus underscores the urgency of conserving ritual plant knowledge. Preserving this biocultural heritage is essential not only for sustaining cultural resilience but also for supporting biodiversity conservation strategies rooted in local wisdom.

Plants in ceremonial

A total of 78 taxa of ritual plants belonging to 42 families were recorded among the Aneuk Jamee Community in South Aceh District, which are used in various ritual traditions typical of the Aneuk Jamee Tribe (Table 2; Figure 4). Two additional names were recorded as synonyms (*Oryza sativa* var. *glutinosa* and *Zea mays* var. *saccharata*) and therefore were not counted as separate taxa. The most commonly used family is Poaceae, which includes 10 taxa. Poaceae is the dominant family found in this study due to its dominant geographical conditions of rice fields and plantations (Nursamsu et al. 2024). The family is one of the most important flowering plant families because of its wide distribution and abundance (Gebashe et al. 2020; Farouk et al. 2023). Apart from the family Poaceae being used as an ingredient in typical rituals in the Aneuk Jamee Tribe, it is also the staple food of the Aneuk Jamee Tribe, which is usually planted seasonally by the community, such as rice and corn, where rice is considered a symbol of prosperity for the community (Sharif et al. 2014; Fukagawa and Ziska 2019; Sen et al. 2020).

It should be noted that the species identification observed was relatively higher compared to the previous study conducted by Sutrisno et al. (2020) which found that the Aneuk Jamee Tribe of South Aceh has extensive knowledge of the use of plants in various rituals, with more than 51 taxa used as ingredients in various traditional rituals of the Aneuk Jamee Tribe. The Karo tribe in North Sumatra utilizes as many as 47 plant taxa consisting of 24 families used in traditional rituals of the Karo Tribe (Apriani et al. 2023). From the Dayak Kanayatn tribe in Kalimantan, by utilizing 26 taxa from 12 plant families used for traditional rituals of gawai, birth, death, opening fields, and marriage (Kholifah et al. 2020; Musmuliadi et al. 2022). The Sasak tribe in West Nusa Tenggara utilizes 22 taxa from 15 families used in the peraq api ritual (Rahayu et al. 2023). The Javanese tribe in Central Java utilizes 22 taxa in the ubarampe ritual, which shows a close relationship between indigenous knowledge and biodiversity (Adinugraha et al. 2024). The Osing tribe in Banyuwangi, East Java, utilizes 78 taxa from 41 families (Nurchayati and Ardiyansyah 2018). This data shows that there is still a variety of plant utilization in terms of rituals. In addition, the number of species found and documented indicates that the vegetation and knowledge of ritual plants in the study area are still preserved (Zemede et al. 2024).

In addition to references from tribes in Indonesia, there are also references to knowledge of ritual plants from other countries, such as the Moroccan people have a good knowledge of ritual plants and a large diversity of plants used in various rituals and religious ceremonies in Morocco. A total of 112 plant taxa grouped into 21 families are used for socio-religious rituals and ceremonies. The most frequently mentioned plant family was Apiaceae (10 species), followed by Fabaceae and Lamiaceae. This study shows that many plant species play an important role in socio-religious rituals and ceremonies in Morocco (Chaachouay et al. 2021). Turning to Brazil, there are 86 species belonging to 37 botanical families utilized by communities in Terreiro, Brazil, that are used in various religious rituals (Pagnocca et al. 2020).

Plant habitus

Based on the plant habitus, herbs dominate with the highest percentage, which is 43.2%. It was followed by trees (13.6%), vines (13.6%), shrubs and bushes (11.1%), and palms (7.4%). This distribution shows the diversity of plant growth forms in the observed ecosystem (Figure 5).

Table 2. Plants in the ceremonial of the Aneuk Jamee Tribe in South Aceh, Aceh, Indonesia

Families	Botanical name	Local name	Habitus	Status	Location found	Part used	Ritual of Aneuk Jamee Tribe	UV	RFC	ICS
Acanthaceae	*Barleria noctiflora* L.f.	*Daun madu*	Herb	Wild	Forest edge	Flower	*Pernikahan*	0.63	0.36	2.6
	Clinacanthus nutans (Burm.f.) Lindau	*Sugi putiah*	Shrub	Wild	Yard, forest edge	Leaf	*Tampung tawar, tulak bala, kanduri ubek padi*	1.07	0.88	169.5
	Justicia gendarussa Burm.f.	*Sugi itom*	Shrub	Wild	Yard, forest edge	Leaf, stem	*Tampung tawar, tulak bala, kanduri ubek padi*	0.89	0.90	169.5
Amaranthaceae	*Amaranthus spinosus* L.	*Bayam duri*	Herb	Wild	Garden, forest edge	Whole plant	*Lahiran*	0.66	0.74	2.30
	Celosia argentea L.	*Bungo bayom*	Herb	Wild	Yard	Leaf, flower	*Lahiran*	0.62	0.53	4.2
Amaryllidaceae	*Allium cepa* L.	*Bawang siah*	Herb	Cultivated	Garden	Rhizome	*Sunatan, pernikahan*	0.62	0.75	83.2
	Allium sativum L.	*Bawang putiah*	Herb	Cultivated	Garden	Rhizome	*Sunatan, pernikahan*	0.63	0.73	103.6
	Crinum asiaticum L.	*Babakuong*	Herb	Wild	Yard, forest edge	Flower	*Pernikahan*	0.65	0.71	5.2
Annonaceae	*Annona muricata* L.	*Dien lando*	Tree	Cultivated	Yard	Leaf, flower	*Tulak bala*	0.63	0.52	31.8
Apocynaceae	*Catharanthus roseus* (L.) G.Don	*Bungo dara*	Shrub	Wild	Yard	Flower	*Pernikahan, mandi baluluak, sunatan*	0.74	0.53	46.8
Araceae	*Colocasia esculenta* (L.) Schott	*Keladi*	Herb	Cultivated	Yard, garden	Tuber, stem, leaf	*Pernikahan dan sunatan*	0.7	0.56	25.8
Araliaceae	*Polyscias scutellaria* (Burm.f.) Fosberg	*Tapak leman*	Shrub	Cultivated	Yard, forest edge	Leaf	*Tulak bala, kanduri ubek padi*	0.56	0.6	22.8
Arecaceae	*Areca catechu* L.	*Pinang*	Tree	Cultivated	Yard, garden	Leaf, flower, seed, fruit	*Pemulia jame, tulak bala, turun tanah, tampung tawa*	0.55	0.84	154.5
	Arenga pinnata (Wurmb) Merr.	*Ijuok*	Tree	Cultivated	Forest edge, forest	Leaf	*Tulak bala, tampung tawa, kanduri ubek padi*	0.65	0.58	56.1
	Cocos nucifera L.	*Karambie*	Tree	Cultivated	Yard	Leaf, fruit, flower	*Pambaok umah kanduri, pernikahan, sunatan, turun tanah, tulak bala, mandi baluluok, antek linto*	1.54	0.76	179.5
	Metroxylon sagu Rottb.	*Sagu*	Tree	Cultivated	Riverbank	Stem	*Rapat ninik mamak, rapat umum, malimpiang*	0.63	0.73	27.2
	Salacca zalacca (Gaertn.) Voss	*Salak*	Tree	Cultivated	Forest edge, swamp edge	Fruit	*Molod*	0.79	0.75	21
	Cyrtostachys renda Blume	*Pinang siah*	Tree	Cultivated	Yard	Whole plant	*Pernikahan*	0.63	0.44	6.3
Asparagaceae	*Cordyline fruticosa* (L.) A.Chev.	*Junjuang*	Shrub	Wild	Yard, rice field	Leaf	*Tampung tawa, tulak bala, kanduri ubek padi.*	0.84	0.71	143.2
Aspleniaceae	*Thelypteris afra* (Christ) C.F.Reed	*Paku cemin aie*	Herb	Wild	Riverbank, forest edge, forest	Leaf	*Tulak bala*	0.69	0.31	29.2
Asteraceae	*Ageratum conyzoides* L.	*Simamih*	Herb	Wild	Garden, forest edge, rice field	Leaf	*Lahiran*	0.64	0.47	32.6
	Bidens pilosa L.	*Bungo adet-adet*	Herb	Wild	Forest edge, forest	Flower	*Pernikahan*	0.57	0.44	22.4
Basellaceae	*Basella alba* L.	*Limayuong*	Climber	Cultivated	Yard	Leaf, flower	*Lahiran*	0.61	0.72	28.1
Bromeliaceae	*Ananas comosus* (L.) Merr	*Noneh*	Herb	Cultivated	Yard	Fruit	*Molod*	0.58	0.48	62.8
Cannaceae	*Canna indica* L.	*Bungo tasbih*	Herb	Wild	Forest edge	Leaf, flower	*Pernikahan*	0.75	0.75	9.8

Caricaceae	*Carica papaya* L.	*Botiek*	Herb	Cultivated	Yard, rice field, garden	Leaf, fruit, flower	*Lahiran, tulak bala*	0.69	0.55	98.4
Combretaceae	*Combretum indicum* (L.) DeFilipps	*Pocah pingen*	Climber	Wild	Yard	Flower	*Mandi baluluok*	0.71	0.44	68.4
Convolvulaceae	*Ipomoea batatas* (L.) Lam.	*Ubi jala*	Vine	Cultivated	Garden	Tuber	*Rapat ninik mamak, rapat umum*	0.57	0.43	67.6
Crassulaceae	*Kalanchoe pinnata* (Lam.) Pers.	*Sidingin*	Herb	Cultivated	Yard	Leaf	*Turun tanah*	0.59	0.72	64.4
Cucurbitaceae	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	*Malikai*	Climber	Cultivated	Rice field, garden	Fruit	*Molod, pernikahan*	0.85	0.79	75.2
	Cucurbita moschata Duchesne	*Labu bosi*	Climber	Cultivated	Garden	Fruit	*Rapat ninik mamak, rapat umum*	0.59	0.71	49.2
	Lagenaria siceraria (Molina) Standl.	*Labu aie*	Climber	Cultivated	Yard, garden	Fruit	*Kanduri ubek padi*	0.63	0.43	52.8
Cyperaceae	*Cyperus rotundus* L.	*Umpuik sowuik*	Herb	Wild	Yard, rice field	Whole plant	*Tampung tawar, tulak bala, kanduri ubek padi*	0.72	0.36	22.8
Dioscoreaceae	*Dioscorea hispida* Dennst.	*Gaduong tanah*	Climber	Wild	Forest edge	Tuber	*Lahiran*	0.83	0.75	62.4
Euphorbiaceae	*Acalypha hispida* Burm.f.	*Ekor kucing*	Herb	Wild	Yard, forest edge	Leaf, flower	*Lahiran*	0.65	0.65	56.1
	Manihot esculenta Crantz	*Ubi togak*	Shrub	Cultivated	Yard, garden, rice field	Tuber	*Rapat ninik mamak, rapat umum, malomang*	0.63	0.46	23
	Codiaeum variegatum (L.) Rumph. ex A.Juss.	*Bungo kubuo*	Shrub	Wild	Yard	Leaf	*Tulak bala*	0.61	0.46	6.3
Fabaceae	*Vigna radiata* (L.) R.Wilczek	*Kacang ijau*	Shrub	Cultivated	Rice field, garden	Seed	*Rapat ninik mamak, rapat umum*	0.61	0.53	43.2
Lamiaceae	*Clerodendrum chinense* (Osbeck) Mabb.	*Bungo susun*	Shrub	Wild	Forest edge	Flower	*Pernikahan*	0.61	0.46	43.2
	Clerodendrum thomsoniae Balf.	*Kantin*	Climber	Wild	Yard	Flower	*Pernikahan*	0.65	0.63	33.2
Lythraceae	*Lawsonia inermis* L.	*Inai*	Shrub	Cultivated	Yard	Leaf	*Pernikahan, sunatan, turun tanah, aqiqah*	1.34	0.87	154.5
Malvaceae	*Durio zibethinus* L.	*Dien*	Tree	Cultivated	Garden, forest edge, forest	Leaf	*Tulak bala, kanduri ubek padi*	0.62	0.59	28.1
	Hibiscus arnottianus A.Gray	*Bungo ayo putiah*	Shrub	Cultivated	Yard	Flower	*Pernikahan, takono*	0.61	0.45	47.1
	Hibiscus rosa-sinensis L.	*Bungo ayo siah*	Shrub	Cultivated	Yard	Flower	*Pernikahan, takono*	0.52	0.30	9.8
Menispermaceae	*Cyclea barbata* Miers	*Cincau*	Climber	Wild	Forest edge	Leaf	*Pernikahan*	0.61	0.66	98.4
Moraceae	*Artocarpus heterophyllus* Lam.	*Cibodak*	Tree	Cultivated	Garden, forest	Leaf, Fruit	*Pernikahan, sunatan*	0.91	0.4	26.4
Musaceae	*Musa acuminata* Colla	*Pisang Abin*	Herb	Cultivated	Yard, garden	Fruit, Stem	*Turun tanah, pernikahan, sunatan*	0.67	0.64	31.8
	Musa balbisiana Colla	*Pisang wak*	Herb	Cultivated	Yard, garden	Fruit, Stem	*Turun tanah, pernikahan, sunatan*	0.61	0.58	25.2
Myrtaceae	*Syzygium malaccense* (L.) Merr. & L.M.Perry	*Jambu boy*	Tree	Cultivated	Yard, garden, forest edge	Leaf	*Pernikahan, sunatan*	0.83	0.52	56.1
Oxalidaceae	*Averrhoa bilimbi* L.	*Limbieng*	Tree	Cultivated	Yard	Leaf, Fruit	*Lahiran, pernikahan*	0.71	0.66	24.6
Nyctaginaceae	*Mirabilis jalapa* L.	*Bungo kombang subuh*	Shrub	Wild	Yard	Flower	*Pernikahan, mandi baluluak, sunatan*	0.64	0.40	12.8
	Bougainvillea spectabilis Willd.	*Bungo koteh*	Bush	Cultivated	Yard	Flower	*Pernikahan, mandi baluluak, sunatan*	0.62	0.53	15.2

Pandanaceae	*Pandanus amaryllifolius* Roxb.	*Panden musang*	Herb	Wild	Yard, forest edge	Leaf	*Mandi baluluok, mandi ayi yayo, aie sembilan*	0.63	0.60	37.8
	Pandanus tectorius Parkinson	*Panden duri*	Herb	Wild	Yard, forest edge	Leaf	*Turun tanah*	0.84	0.47	24.4
Piperaceae	*Piper betle* L.	*Sirih*	Vine	Cultivated	Yard, garden	Leaf	*Pernikahan, antek tando, turun tanah, tampung tawa, sunatan, angkek umah, rapek ninik mamak, rapek umum, pemulia jame*	1.47	0.51	179.5
	Piper sarmentosum Roxb.	*Sirih air*	Shrub	Wild	Forest edge	Leaf	*Tulak bala*	0.65	0.73	23.2
	Piper nigrum L.	*Lado ketek*	Climber	Cultivated	Yard, garden	Fruit	*Lahiran*	0.63	0.33	9.8
Poaceae	*Bambusa bambos* (L.) Voss	*Buluoh*	Herb	Cultivated	Forest edge, riverbank	Stem	*Tampung tawar, tulak bala, kanduri ubek padi, malomang, mak meugang*	0.61	0.62	37.2
	Bambusa vulgaris Schrad. ex J.C.Wendl.	*Buluoh kuniang*	Herb	Cultivated	Forest edge, riverbank	Stem	*Tampung tawar, tulak bala, kanduri ubek padi*	0.62	0.48	39.2
	Cymbopogon citratus (DC.) Stapf	*Sereh*	Herb	Cultivated	Yard, garden, rice field	Leaf, Stem	*Tulak bala, kanduri ubek padi,*	0.61	0.68	25.8
	Imperata cylindrica (L.) Raeusch.	*Daun padang*	Herb	Wild	Garden, rice field, forest edge	Whole Plant	*Lahiran*	0.66	0.69	35.2
	Oryza sativa L	*Padi*	Herb	Cultivated	Rice field	Seed	*Tampung tawar, malimpiang, antek fitrah*	0.82	0.64	179.5
	*Oryza sativa L. (*syn. *Oryza sativa* var. *glutinosa)*	*Padi puluik*	Herb	Cultivated	Rice field	Seed	*Pernikahan, sunatan, turun tanah, tampung tawar, angkeh umah, kandui padi, malom naik kaji, malom patomet kaji, bukak lahan, tulak bala, molod, lahiran, takono, mak meugang, buek teraktak, aqiqah, malomang*	1.57	0.86	179.5
	Saccharum officinarum L	*Tobu botuong*	Herb	Cultivated	Riverbank, forest edge	Stem	*Turun tanah, molod, antek linto*	0.61	0.77	74.7
	Saccharum officinarum L.	*Tobu siah*	Herb	Cultivated	Yard, rice field	Stem	*Turun tanah, molod, antek linto*	0.82	0.45	65.4
	Zea mays L.	*Jaguang*	Herb	Cultivated	Rice field, garden	Seed	*Tampung tawa*	0.67	0.71	71.4
	Zea mays L. (syn. *Zea mays* var. *saccharata)*	*Jaguong manih*	Herb	Cultivated	Rice field, garden	Seed	*Rapat ninik mamak, rapat umum*	0.61	0.72	37.6
Rosaceae	*Malus domestica* (Suckow) Borkh.	*Apel*	Tree	Cultivated	Garden	Fruit	*Molod, lahiran*	0.83	0.43	65.7
Rubiaceae	*Coffea canephora* Pierre ex A.Froehner	*Kopi*	Bush	Cultivated	Yard, garden	Seed	*Pernikahan, sunatan, turun tanah, angkek umah, buek teratak, antek linto*	0.71	0.50	52.8
	Morinda citrifolia L.	*Mengkudu*	Tree	Cultivated	Yard	Leaf	*Tulak bala*	0.64	0.38	59.1
	Uncaria gambir (W.Hunter) Roxb.	*Gambie*	Tree	Cultivated	Forest edge	Fruit	*Pernikahan, pemulia jame*	0.62	0.51	43.4
Rutaceae	*Citrus × aurantiifolia* (Christm.) Swingle	*Asom kaco*	Tree	Cultivated	Garden	Fruit	*Pernikahan*	0.63	0.57	25.2

	Citrus hystrix DC.	*Asom limau purut*	Tree	Cultivated	Garden	Fruit	*Mandi ayi yayo, aie sembilan*	0.84	0.33	27.2
	Citrus maxima (Burm.) Merr.	*Jeruk bali*	Herb	Cultivated	Yard	Fruit	*Pernikahan*	0.7	0.4	49.2
Selaginellaceae	*Selaginella doederleinii* Hieron.	*Paku ayom*	Shrub	Wild	Forest edge	Whole Plant	*Tulak bala*	0.65	0.43	25.6
Solanaceae	*Capsicum frutescens* L.	*Lado godang*	Shrub	Cultivated	Yard, garden	Fruit	*Lahiran, pernikahan*	0.63	0.62	68.7
	Capsicum annuum L.	*Lado unggeh*	Herb	Cultivated	Yard, garden	Fruit	*Lahiran*	0.61	0.38	61.8
Zingiberaceae	*Alpinia galanga* (L.) Willd.	*Langkuweh*	Herb	Cultivated	Yard, garden	Rhizome	*Lahiran*	0.62	0.69	37.6
	Kaempferia galanga L.	*Bolei*	Herb	Cultivated	Yard, garden	Rhizome	*Pemulia jame, rapat ninik mamak, rapek umum, antek tando*	0.61	0.72	86.8
	Curcuma longa L.	*Kunik*	Herb	Cultivated	Yard, garden	Rhizome	*Lahiran, takono*	0.66	0.43	120.5

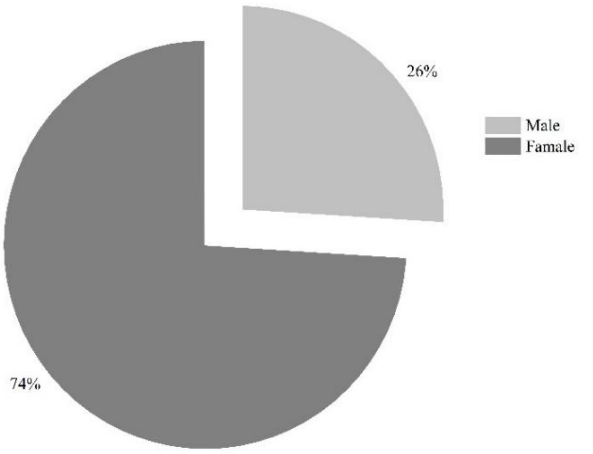

Figure 2. Gender distribution of respondents

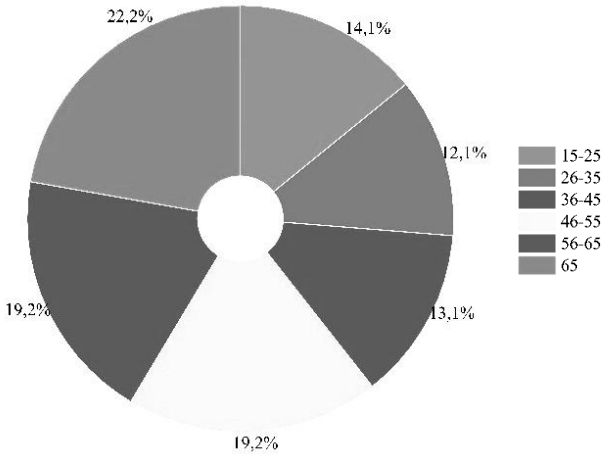

Figure 3. Distribution of respondents across age categories

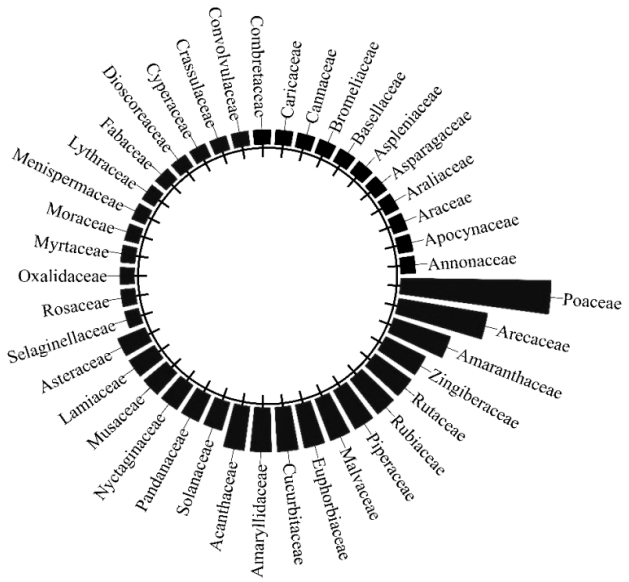

Figure 4. Distribution of ritual plant species across 42 families recorded among the Aneuk Jamee Community in South Aceh, Indonesia

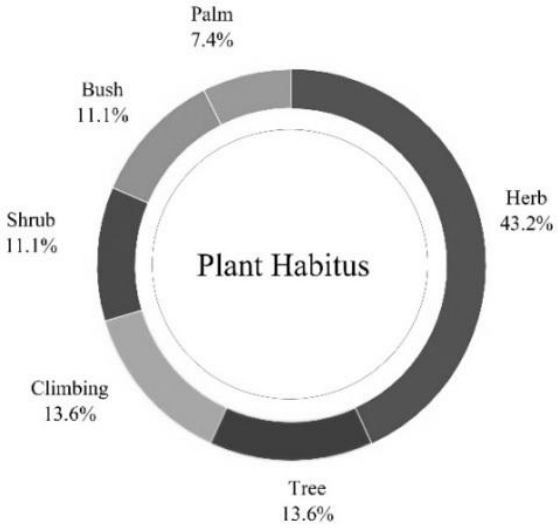

Figure 5. Distribution of plant habitus among ritual plants used by the Aneuk Jamee Tribe in South Aceh, Indonesia

This diversity of plant species indicates a rich ecosystem, where each category has a different role in the environment (Li et al. 2022). The dominance of herb species indicates their importance in providing ground cover, supporting soil stability, and being a food source for a variety of organisms. Trees, at a substantial percentage, contribute significantly to carbon sequestration, provide shade, and create habitat for wildlife. Vine plants add vertical structure to the ecosystem, allowing for increased light capture and biodiversity. Shrubs, although less numerous, offer important cover and food for many species, while the small percentage of grasses and palms demonstrate their specific ecological niche. Overall, this distribution emphasizes the interconnectedness between these plant groups and their contribution to a balanced and thriving ecosystem (Losapio et al. 2024).

Plant status and native habitat

Based on the plant status, cultivated species are more dominant when compared to wild plants, with the percentage of cultivated plants of 71 taxa (77.2%) and wild plants of 21 taxa (22.8%). Meanwhile, the habitat of ritual plants is dominated by yards with a percentage of 36.1%, followed by gardens (24.8%), forest edges (20.3%), rice fields (10.5%), forests (3.8%), riverbanks (3.8%), and wetland edges (0.8%) (Figure 6).

The status of wild and cultivated plants reflects the difference in sustainability and utilization conditions between naturally growing and cultivated plants. Cultivated plants are developed through human intervention, with the aim of increasing productivity, quality, or plant resistance to certain environmental conditions. Wild plants, on the other hand, often grow in their native habitats without human intervention, adapted to their surroundings and have

important ecological value as guardians of the biodiversity balance and providers of food sources and natural medicines for local fauna. Their status highlights the importance of maintaining a balance between the utilization of wild and cultivated plants, as well as the implementation of sustainable cultural practices that consider conservation and ecosystem balance. Cultivation of ritual plants in both cultivated and wild forests should also be commercially viable, as cultivation of ritual plants in forests does not alter the function of the forest as a producer of environmental services (Sutrisno et al. 2020).

The most common plants in this study were found in home garden, a garden land that is often utilized and easily accessible when needed and provides various ecosystem services, both directly and indirectly (Sarkar et al. 2019). Home-garden systems not only aim to provide materials for rituals, but also food security, nutrition, and daily household consumption (Whitney et al. 2017; Hanun et al. 2023). In addition, it is also utilized in growing other products such as medicinal materials, fuel, construction materials, and ornamental items that have important values (Wiryono et al. 2016). Home yards play an important role in supporting the livelihoods of local communities by utilizing the plants grown in the yard (Yadav et al. 2018).

Home yards are used to provide food and medicine to fulfill daily needs in Aceh (Mardudi et al. 2020; Ramaidani and Navia 2020a; Saudah et al. 2021, 2022; Suwardi et al. 2023; Nursamsu et al. 2024), while peoples in West Java utilize yard plants for food, medicine, ornamental plants, industrial materials, and other uses (Raihandhany and Purnomo 2025). In Kampung Masjid Ijok, Perak, Malaysia, homeyard agroforestry consists mainly of food, medicinal, and ornamental plants (Ramli et al. 2021). Home gardens in Sri Lanka provide low-cost food security throughout the year, especially for poor farmers (Moricca et al. 2023). Similarly, in rural Africa, home gardens support smallholder food security (Gifawesen et al. 2020).

The predominance of cultivated species (77.2%) further underscores the role of home gardens and agroecosystems as biocultural reservoirs that sustain both ecological availability and cultural continuity (Quiroz et al. 2016; Navia et al. 2020a). Staple crops such as *O. sativa* and *Z. mays* symbolize prosperity and fertility, while ritual ornamentals such as *Cordyline fruticosa* represent purification. This interdependence between ecological landscapes and ritual practices highlights how plant availability shapes cultural salience.

Quantitative indices of ritual plant use

Quantitative ethnobotanical indices, such as Use Value (UV), Relative Frequency of Citation (RFC), and Index of Cultural Significance (ICS), were applied to assess the cultural salience of ritual plants among the Aneuk Jamee Community. These indices, when combined, provide a comprehensive understanding of both the functional roles and symbolic meanings of plant species used in traditional ceremonies. Several species consistently scored high across all indices, reflecting their central roles in ritual life (Table 2). *Oryza sativa* var. *glutinosa* (UV=0.86; RFC=179.5; ICS=179.5) emerged as the most culturally significant species, extensively used in ceremonies such as weddings, circumcisions, childbirth rituals, and harvest offerings. *Justicia gendarussa* (UV=0.90; RFC=169.5; ICS=169.5) and *Clinacanthus nutans* (UV=0.88; RFC=169.5; ICS=169.5) also demonstrated high values, reflecting their repeated use in protective rituals like *tampung tawar* and *tulak bala*. Similarly, *Lawsonia inermis* (UV=0.87; ICS=154.5) and *Areca catechu* (UV=0.84; ICS=154.5) are frequently incorporated into marriage and transitional life events. *Cocos nucifera* (UV=0.76; ICS=179.5) stands out for its multifunctionality across ceremonies, ranging from *pemulia jamee* to *mandi baluluok*. Additionally, *C. fruticosa* (UV=0.71; ICS=143.2) and *Curcuma longa* (UV=0.40; ICS=120.5) represent plants with both spiritual and medicinal significance, while *Piper betle* (UV=0.51; ICS=179.5) and *O. sativa* (UV=0.64; ICS=179.5) further emphasize the symbolic and material importance of staple and ritual plants.

The combination of high UV, RFC, and ICS values across these top ten plant species *O. s.* var. *glutinosa, O. sativa, C. nucifera, P. betle, J. gendarussa, C. nutans, L. inermis, A. catechu, C. fruticosa,* and *C. longa* highlights their dual roles as both materially useful and symbolically potent components of ritual practice (Table 2). Their cultural salience underscores the need to prioritize these species for conservation and ethnobotanical education, ensuring that traditional knowledge is preserved and transmitted across generations.

Similar findings have been reported among Malay, Thai, and Filipino communities, where plants such as rice, betel, and coconut carry layered meanings in birth, marriage, and death ceremonies (Teixidor-Toneu et al. 2018). Moreover, many ritual plants also hold medicinal value, including *C. longa,* and *J. gendarussa*. This functional overlap between ethnomedicine and ritual symbolism reflects a dual-purpose use of plants, wherein ceremonial practices also serve healing functions. Such ethnopharmacological convergence has been widely documented among Balinese, Thai hill tribes, and other Southeast Asian ethnic groups, where ritual and medicine often intersect (Boonma et al. 2023).

Use Value (UV)

The Use Value (UV) index was applied to assess the cultural importance and frequency of use of ritual plants among the Aneuk Jamee Community. UV values ranged from 0.52 to 1.57 (Figure 7, Table 2), with the highest recorded for *O. sativa* (1.57), followed closely by *C. nucifera* (1.54) and *P. betle* (1.47). These plants appeared across multiple ceremonial contexts, such as weddings, circumcisions, house blessings, and agricultural rituals, reflecting their multifunctionality and symbolic indispensability. Some species, such as *L. inermis* (1.34), *C. nutans* (1.07), and *Artocarpus heterophyllus* (0.91), also scored highly, indicating their ritual utility in specific functions, including body ornamentation, spiritual protection, and ritual meals. The high UV values of these plants suggest their embeddedness in traditional ceremonial systems and frequent, repeated application.

Relative Frequency of Citation (RFC)

The Relative Frequency of Citation (RFC) index was used to quantify the proportion of informants who cited each plant. RFC values ranged from 0.30 to 0.90 (Figure 7, Table 2). The highest RFC was observed for *J. gendarussa* (0.90), followed by *C. nutans* (0.88), *L. inermis* (0.87), and *O. sativa* (0.86). This suggests a strong degree of consensus within the community regarding the ritual importance of these species. Notably, *A. catechu* (0.84), *Citrullus lanatus* (0.79), and *Saccharum officinarum* (0.77) were also frequently mentioned, underscoring their significance in ceremonial offerings and transition rituals. The high RFC values reflect not only shared knowledge but also the continuity of these practices across generations.

Index of Cultural Significance (ICS)

The Index of Cultural Significance (ICS) offers a composite measure that includes frequency of use, diversity of use contexts, and perceived importance (Figure 8). The three species with the highest ICS, i.e., *C. nucifera*, *P. betle*, and *O. sativa,* each scored 179.5, identifying them as cultural keystone species in the Aneuk Jamee ritual system. These plants are universally incorporated across diverse rituals and are valued not only for their functional properties but also for their deep symbolic meanings. For instance, *C. nucifera* was used in cleansing, offerings, and protection; *P. betle* is central to social and communal ceremonies; and *O. sativa* is symbolic of prosperity and spiritual nourishment. Other plants with high ICS values include *C. nutans* and *J. gendarussa* (169.5), *A. catechu* and *L. inermis* (154.5), *C. fruticosa* (143.2), and *C. longa* (120.5). These results suggest that while some plants are universally used, others hold specific ceremonial value that may be linked to particular rites or seasonal events (Table 2).

Part used

Plant parts are the main components utilized from a plant. Leaf (30.4%) is the most commonly used, followed by fruit (20.6%), flower (18.6%), stem (9.8%), seed (6.9%), all parts (4.9%), rhizome (4.9%), and tuber (3.9%) (Figure 9). This data highlights that leaves are the most commonly used part by the Aneuk Jamee Tribe due to their ease of processing in various types of rituals when compared to other plant parts (Ismail and Ahmad 2019; Helmina and Hidayah 2021; Nehru et al. 2024). Leaves are the most important plant organ and carry out vital physiological activities, such as photosynthesis, respiration, transpiration, photoreception, and the synthesis and supply of signal compounds, including growth regulators (Roth-Nebelsick and Krause 2023). Fruits represent the second most frequently used plant part after leaves. They serve as an essential source of nutrition for both humans and animals, providing carbohydrates, vitamins, antioxidants, trace elements, and dietary fiber (Liu et al. 2022). In addition, fruits are commonly incorporated into a wide variety of ritual dishes and ceremonial offerings (Suparman and Nuruahmad 2023; Yani et al. 2024).

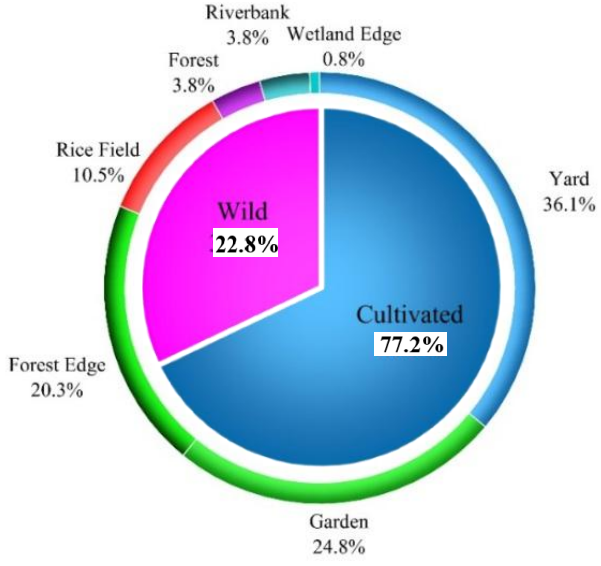

Figure 6. Cultivation status and habitats of ritual plants recorded among the Aneuk Jamee Tribe in South Aceh, Indonesia

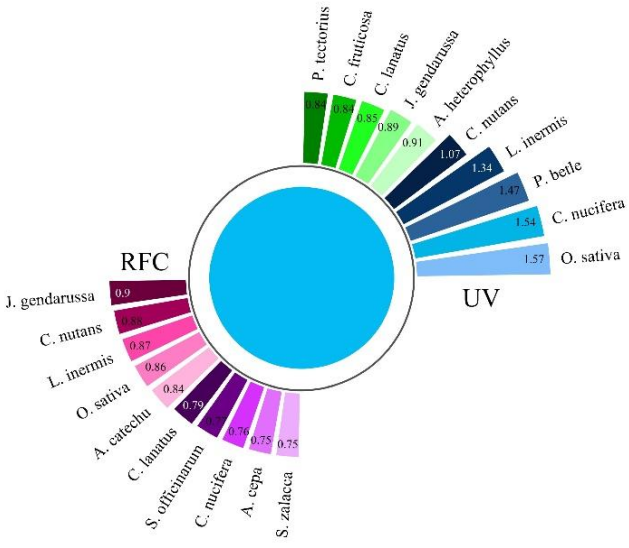

Figure 7. Use Value (UV) and Relative Frequency of Citation (RFC) of plants recorded in the Aneuk Jamee Tribe, South Aceh, Indonesia

Ritual categories and plant use patterns

The ethnobotanical survey revealed that ritual plant use is distributed across various ceremonial contexts. The highest number of plant taxa was associated with wedding ceremonies (WD) (70 taxa), followed by circumcision rituals (CC) (47 taxa), birth-related traditions (BR) (46 taxa), and mystical ceremonies (MT) (24 taxa). Fewer species were recorded for Islamic holidays (IH) (15 taxa), agricultural rites (RG) (12 taxa), and death ceremonies (DT) (4 taxa), while religious structures (RL) and buildings (BL) accounted for only 2 taxa each (Table 3; Figure 10). These results demonstrate that the most plant-diverse rituals are centered on life transitions, such as marriage, childbirth, and coming-of-age, indicating their complexity and centrality in Aneuk Jamee cultural life. At the same time, certain species such as *J. gendarussa* and *Annona muricata* are specifically incorporated for mystical protection, reflecting localized cosmological beliefs rooted in ancestral reverence and Islamic mysticism traits less emphasized in Buddhist or animist communities of mainland Southeast Asia. This distinctive feature highlights a unique biocultural synthesis in which Islamic ecological ethics and local traditional knowledge intersect to shape ritual plant selection.

Table 3. Typology of ritual practices and associated plant use

Ritual type	Specifik ritual name	Number of plant species	Key species	Cultural role
Wedding (WD)	*Pernikahan, mandi baluluok, tampung tawa, antek linto, rapat ninik mamak, rapat umum, pemulia jame, pambaok umah kanduri, buek teratak, antek tando*	70	*Piper betle, Oryza sativa, Cocos nucifera*	Prosperity, social unity
Circumcision (CC)	*Sunatan, tampung tawa, mandi baluluok, rapat ninik mamak, rapat umum, pemulia jame, pambaok umah kanduri, buek teratak*	47	*Clinacanthus nutans, Lawsonia inermis*	Rite of passage, purification
Birth (BR)	*Lahiran, tampung tawa, turun tanah Aqiqah, basilek*	46	*Curcuma longa, Capsicum annuum*	Protection, maternal health
Death (DT)	*Aie sembilan, malimpiang*	4	*Citrus hystrix, Pandanus amaryllifolius*	Funeral rite, farewell ritual
Agricultural (RG)	*Kanduri ubek padi, bukak lahan*	12	*Justicia gendarussa, Cordyline fruticosa*	Field blessing, pest deterrent
Islamic holidays (IH)	*Molod, mandi ayi yayo, antek fitrah, mak meugang, malomang*	15	*Oryza sativa, Bambusa bambos*	Thanksgiving, religious commemoration
Mystical (MT)	*Takono, tulak bala*	24	*Clinacanthus nutans, Thelypteris afra*	Ward off spirits, spiritual cleansing

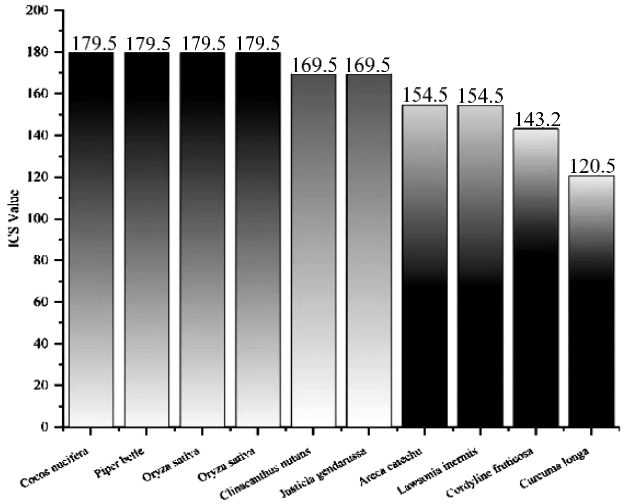

Figure 8. Index of Cultural Significance (ICS) of plants recorded in the Aneuk Jamee Tribe, South Aceh, Indonesia

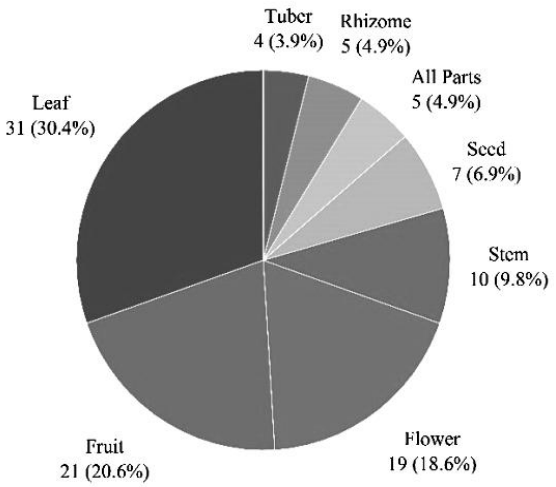

Figure 9. Part used in ritual practices among the Aneuk Jamee Community in South Aceh, Indonesia

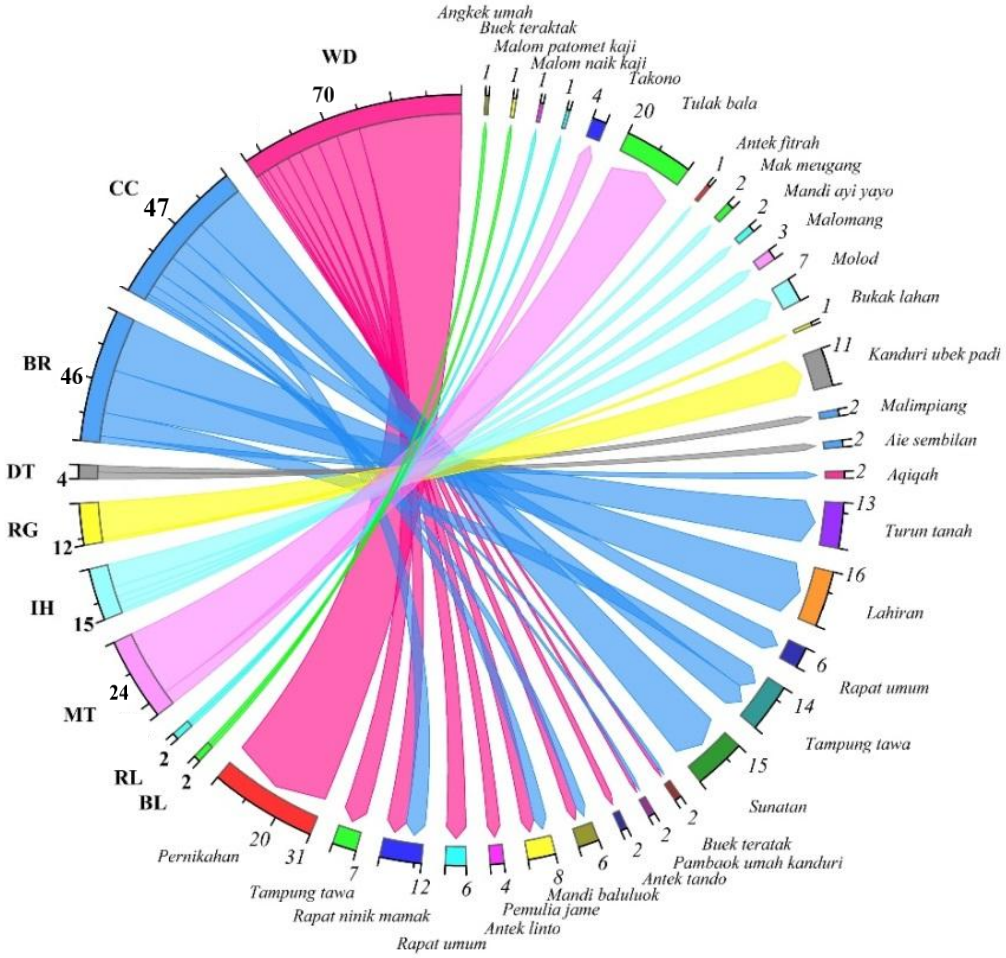

Figure 10. Plant used in the ceremonial among the Aneuk Jamee Community in South Aceh, Indonesia

Wedding ceremony

Antek tando

Antek tando is a tradition carried out by the Aneuk Jamee Tribe who want to propose to girls in order to tie a relationship that will later be married. In the *antek tando* tradition, from the male family, there must be an intermediary called Wali, and the male side must bring a betel pack as a word opener (*pemulia jamee*), which contains *P. betle*, *A. catechu, Uncaria gambir, Kaempferia galanga,* and *Citrus hystrix* (Figure 11.A). Betel nut is a symbol of respect and togetherness (Rismawati and Cahyuni 2023). It is no longer considered an actual plant, but was used as a symbol to convey meaning. Each region has its own beliefs and meanings in carrying out this tradition, and they develop their respective philosophies based on local cultural wisdom (Astuti et al. 2024). Betel nut has become a legacy passed down by the ancestors or *tete nene* ancestors to foster togetherness in unity and maintain harmony and kinship in the unity of indigenous peoples and also harmony, complementarity, and mutual improvement (Touwely et al. 2020).

Pemulia jame

Pemulia jame is usually a tradition to start a conversation (opening words) when someone is visiting or when they want to propose to someone (Roslaili 2019). The groom's family (*anak linto*) usually brings betel (*P. betle*) leaves that have been prepared and decorated with areca nut (*A. catechu*) and other equipment, such as *bolai* (*K. galanga*), *gambier* (*U. gambir*), and *Citrus* × *aurantiifolia*, of course which, will be given to the girl's family (*anak daro*) (Nursita et al. 2020).

Rapat ninik mamak

Rapat ninik mamak is a tradition carried out by the community in the form of a large family meeting that wants to hold a feast at their home. This tradition is a form of family deliberation in order to get a solution and an overview of the *kenduri* event to be held.

Rapat umum

Rapat umum is a community tradition held in the form of a general meeting, usually organized in preparation for a communal feast (*kenduri*) at a community house. Unlike the more restricted *rapat ninik mamak*, general meetings are open to everyone, allowing broader community participation. This practice reflects the principle of mutual assistance, as attendees contribute monetary donations to ease the financial burden of the host family. Contributions are recorded and later reciprocated when other households

organize similar events, thus strengthening reciprocal social obligations. During the general meeting, food is traditionally served in the form of porridge made from mung beans (*Vigna radiata*), corn (*Z. mays*), and sweet potatoes (*Ipomoea batatas*), which is prepared in advance and distributed collectively as part of the shared labor (*gotong royong*). Such culinary traditions not only provide nourishment but also reinforce social bonds and cultural identity. Food practices function as daily affirmations of community values and symbolic expressions of rituals, traditions, and social events. Importantly, food culture is always context-specific, meaning that the traditions in one community may differ significantly from those in another (Wijaya 2019).

Buek teraktak

Buek teraktak is a tradition of making tents for families who are conducting a wedding party carried out by all young people and parents, especially men, while women prepare food in the form of yellow sticky rice (*O. s.* var. *glutinosa*) wrapped in banana leaves and served with black coffee. The yellow sticky rice symbolizes a noble goal and is supported by black coffee, which symbolizes the spirit of cooperation. Coffee is considered a source of stamina during the process of making party tents (Djami 2022). The tradition of drinking coffee in various activities makes it not just a drink, but a symbol of togetherness and cultural identity (Alamsyah et al. 2024).

Malom ba inai

Malom ba inai is a tradition of coloring the hands and feet of the bride and groom (*anak linto*) and the bride (*anak daro*) who are getting married, which is done in the evening before the peak event tomorrow. This event is usually carried out by girls and mothers who work together to pick and smooth henna leaves (*L. inermis*) before *malom ba inai* (Putri et al. 2017; Perrina 2022). Coloring the palms and feet of the bride has the meaning of fertility, beauty, and the bride is ready for marriage (Figure 11.R) (Sutrisno et al. 2020; Maharani and Fitri 2022).

Mandi baluluok

Mandi baluluok is a tradition of bathing with water that has been mixed with mud and flowers (*Catharanthus roseus, Mirabilis jalapa*, and *Bougainvillea spectabilis*), which is done before the bride and the child who wants to be circumcised wears a wedding dress (Indaty et al. 2018). This tradition has a meaning to be humbler and not forget their origin from the ground (Figure 11.B).

Balai daun jambu

Balai daun jambu is a traditional event decoration that is made when there is a marriage, which is usually placed next to the aisle or bridal throne. This *balai* is usually made from guava (*Syzygium malaccense*) leaves of which are decorated in such a way on small banana stems (*Musa acuminata* and *M. balbisiana*). This tradition has long been made with the meaning to obtain prosperity and success, like the *balai made*.

Acara puncak

Acara puncak is the culmination of the wedding, which at this peak event is considered the most sacred. Marriage is a complex form of tradition where there are many rituals that must be carried out. The wedding ceremony is usually carried out for up to seven days, starting from the general meeting to *antek linto*, namely delivering the bridegroom to the bride's house (Sutrisno et al. 2020).

Circumcision ceremony

Basunet

Basunet is a tradition carried out by the Aneuk Jamee Tribe for boys who are about to enter puberty (Sholeh and Zahiroh 2017). *Basunet* is the culmination of the *sunatan* event, which at this peak event is the most sacred which is done once in a lifetime for the child. Just as the traditional ritual process is carried out with marriage, circumcision is also carried out with a series of processes starting from the *rapat ninik mamak-rapat umum-buak teraktak-malom ba inai-basunet*. *Basunet* is a self-cleansing ritual for the child who has reached the end of puberty, who must undergo a period of circumcision to be cleansed from uncleanliness (Figure 11.O) (Lestari et al. 2023; Nurlina et al. 2023).

Birth ceremony

Badapuo

Badapuo is a customary tradition carried out by mothers who have given birth to take a rest, not leave the house for 40 days, and cannot eat prohibited foods, such as oil, and itchy foods. During *badapuo*, there is a special food that is intended for mothers who are badapuo, namely majun, a type of food made from glutinous rice (*O. s.* var. *glutinosa*) which is steamed and then pounded until smooth and then added with turmeric (*C. longa*), pepper (*Piper nigrum*), and also cayenne pepper (*Capsicum annuum*). These foods aim to keep the mother's stomach warm (Zumaidar et al. 2019a, b).

Turun tanah

Turun tanah is performed when a boy has just finished childbirth, or in the local language called "*Duduk dapu*" where the child will be taken out of the house and stepped on the ground. The ritual of getting off the ground is the first moment a child sets foot on the ground (Nurfajri et al. 2016). This ritual is a symbol to introduce the child to the surrounding environment. In this first descent procession, in addition to introducing nature (land) as a place to stand. Uniquely for baby girls will be introduced to taste a little sugar on their lips and forehead as a symbol that later the child will grow up to be a sweet and beautiful child and for baby boys will be attached to rice on their foreheads as a symbol that later they will be strong in seeking sustenance and hard workers. The procession of this first descent will be carried out by religious leaders and role models in the community, where the family or parents will invite or bring the baby to the place of the pious or ulama to carry out the procession who will carry the baby from the kitchen to the door of the house (Figure 11.P) (Karimuddin 2022).

Basilek

Basilek is a series of traditions where religious leaders/community leaders who are seen to be performing martial arts or people call it "*basilek*" will carry the baby from the door of the house. After that, the child is taken outside and an old coconut (*C. nucifera*) is split right in front of the baby and the coconut that has been split into two parts will be thrown one side of the coconut from the front of the house to the back, and the other side of the coconut will be thrown from the right side to the left of the house. The symbol of throwing the coconut from the side of the house is interpreted as a way to drive away the devil and remove the bad side in the life of the future child. After that, the religious leader will perform *silat*, which will cut the banana (*Musa* sp.) which symbolizes a bland life. Followed by cutting an areca nut (*A. catechu*) tree which symbolizes a bitter life, and finally cutting a sugar cane (*S. officinarum*) which symbolizes a sweet life or glory. This tradition is carried out as a symbol of the child's life journey that will begin from that day (Figure 11.Q) (Sutrisno et al. 2020).

Aqiqah

Aqiqah is one of the sunnah *muakkadah* that is recommended to be carried out by Muslim parents as a form of gratitude to Allah for the birth of a child. The tradition involves slaughtering an animal, usually a goat, on the seventh day after the birth of the child, shaving the baby's hair, and giving the child a name (Siregar and Siregar 2024). Although *aqiqah* is not an obligation, this tradition has many benefits and wisdom behind it. The social benefit of aqiqah is to share happiness with others and help the poor. The spiritual benefits of *aqiqah* are to atone for sins and pray for the safety of the child (Sikumbang et al. 2024).

Death ceremony

Aie sembilan

Funerals are a series of rituals that take place from death to burial, which generally involve many people and are characterized by gathering and praying (de Grave 2018). In the Aneuk Jamee Tribe, the use of plants is often used, especially in the procession of bathing the corpse. The plants used in the form of a water mixture called "*aie sembilan*" contain various types of plants, such as *C. hystrix* and *Pandanus amaryllifolius*. Water that has been mixed with fragrances and plants will then be poured onto the corpse nine times during the procession of bathing the corpse (Sutrisno et al. 2020).

Malimpiang

Malimpiang is a tradition where *limpiang* (*apam*-like food) made from rice (*O. sativa*) is made for death events, such as the seventh night of the deceased. This food will be the main meal at the event, which is served with a sauce made of coconut milk (*C. nucifera*) and brown sugar (*Arenga pinnata*) (Figure 11.M).

Rice field and garden ceremony

Kanduri ubek padi

Kanduri ubek padi is a *kanduri* that is usually carried out during the season of newly planted rice fields with the aim of being more blessed so that the results are good and avoid drought, pests and animals that destroy rice plants. *Kanduri ubek padi* usually consists of several series of activities, starting from praying together to eating together. In this tradition, there are several plants that are used, including *C. nutans, J. gendarussa, Polyscias scutellaria, A. pinnata, C. fruticosa, Cyperus rotundus, Durio zibethinus, Bambusa bambos, B. vulgaris, Cymbopogon citratus,* and *Lagenaria siceraria*. This tradition is usually made after the community has planted rice simultaneously and is usually carried out close to irrigation and rice field irrigation sources (Figure 11.K).

Bukak lahan

Bukak lahan tradition is a kanduri and prayer activity carried out by people who want to open new land. This traditional activity has a meaning so that the newly opened land gets a blessing and the land opened gets fertility (Figure 11l).

Islamic holiday ceremony

Balei molod

Balei molod is a tradition of commemorating the birthday of the Prophet Muhammad SAW, which is carried out by the community as a form of love for the Prophet Muhammad SAW (Zhou 2024). This tradition is carried out in the month of the prophet's birth only which is made by the community to do the *maulid dhikr* together and will be served various types of food and fruits. At the time of the celebration, the Aneuk Jamee Tribe was very enthusiastic and usually made a "*balai*" (wooden frame) which was decorated as a place to put fruit and food, which would later be served to guests invited to the remembrance (Figure 11.T).

Antek boreh fitrah

Antek boreh fitrah is a tradition carried out at the time of Eid al-Fitr, where rice (*O. sativa*) is given as a symbol of purification of self and family. *Malomang* is a tradition that has long been carried out among the Aneuk Jamee Tribe where when they celebrate Eid al-Fitr or Eid al-Adha, the community simultaneously cooks *lemang* made of bamboo (*B. bambos*), which is filled with glutinous rice and banana leaves to welcome the feast as the main dish.

Mak meugang

Mak meugang is a tradition that has long been carried out among the Aneuk Jamee Tribe where when they want Eid al-Fitr or Eid al-Adha, the community simultaneously cooks *lemang* and gathers family before heading to the holy day of Eid al-Fitr and Eid al-Adha.

Figure 11. Ceremonial traditional documented among the Aneuk Jamee Community in South Aceh, Aceh, Indonesia: A. *Antek tando*, B. *Mandi baluluok*, C. *Pernikahan*, D. *Tampung tawa*, E. *Tampung tawa*, F. *Antek linto*, G. *Antek linto*, H. *Tampung tawa*, I. *Puluik kuniang*, J. *Malomang*, K. *Kanduri ubek padi*, L. *Bukak lahan*, M. *Malimpiang*, N. *Basunet*, O. *Basunet*, P. *Turun tanah*, Q. *Basilek*, R. *Malom ba inai*, S. *Tepak sirih*, T. *Balei molod*

Mandi ayi yayo

Mandi ayi yayo is a ritual bathing practice performed on the morning of Eid, using water infused with aromatic plants such as *C. hystrix* and *P. amaryllifolius*. This ritual is conducted before attending the Eid prayers and symbolizes renewal and purification. A traditional belief among the Aneuk Jamee holds that those who do not bathe on the morning of Eid will "grow horns," an expression used by parents to teach children about cleanliness and personal hygiene during important religious celebrations.

A ceremony to ward off bad luck and mysticism

Tulak bala

Tulak bala is a traditional communal ceremony practiced by the Aneuk Jamee Community to ward off misfortune and disease, with the aim of safeguarding the well-being and prosperity of all villagers. The ritual involves the collective participation of the community, who gather at a site believed to harbor negative energy or be inhabited by malevolent spirits (jinn). During the ceremony, participants recite verses from the Qur'an together as a spiritual act of purification and protection,

symbolizing the removal of harmful influences from the environment. As part of this tradition, a wide variety of plants are assembled into a single arrangement. These include *C. nutans, J. gendarussa, A. muricata, P. scutellaria, A. catechu, A. pinnata, Thelypteris afra, Carica papaya, Codiaeum variegatum, D. zibethinus, Piper sarmentosum, B. bambos, B. vulgaris, C. citratus, Morinda citrifolia, Selaginella doederleinii, K. galanga, P. nigrum, C. fruticosa, Z. mays, C. longa, Canna indica,* and *Combretum indicum.* Each plant contributes to the symbolic and ritualistic meaning of the ceremony, reinforcing its role as a collective act of cultural identity and spiritual resilience.

Takono

Takono is an incident where someone is sick, believed to be caused by jinn interference and this tradition is carried out as a symbol of peace between humans and jinn. The Aneuk Jamee Tribe believes that there are diseases caused by the jinn. Therefore, people who are sick due to jinn interference are made takono. In general, plants such as *Hibiscus arnottianus, H. rosa-sinensis,* and *O. sativa* are used, which will later be placed in locations that are considered to cause illness, usually near swamps and forests.

Conservation efforts in the sustainability of ritual plants

Ritual plant conservation efforts rely heavily on the active role of the community, including the younger generation, in conserving plants that have cultural and spiritual values. Culture certainly plays an important role in the lives of Aneuk Jamee people, especially in the use of various types of ritual plants (Samad 2015; Nurfajri et al. 2016; Geng et al. 2017). In local communities, the older generation has certainly practiced and preserved their traditional ceremonies, either directly or indirectly, and can maintain genetic resources, especially those related to the use of various plants in traditional ceremonies (Mutaqin et al. 2018).

The younger generation has an important role in preserving ritual plants by utilizing traditional knowledge that has been passed down and applying it in everyday life. Through education and counseling on the importance of ritual plant conservation, the younger generation can be taught to plant and care for these plants in their surrounding environment, such as in home gardens or other open areas. In addition, by utilizing technology and innovation, the younger generation can also develop new ways to introduce and promote ritual plants to the wider community, so as to ensure the sustainability of their utilization and conservation in the long term (Sutrisno et al. 2020). In this case, the younger generation not only acts as a successor to tradition, but also as an agent of change that brings local traditions and knowledge towards a more modern and relevant sustainability. Traditional communities and the younger generation certainly need to maintain traditional culture and social norms are very useful in natural resource conservation (Sada and Jumari 2018).

In conclusion, this study met its aim of documenting and interpreting the diversity and cultural roles of ritual plants used by the Aneuk Jamee Community in South Aceh. The 78 recorded taxa highlight a rich biocultural tradition in which plants serve both practical and symbolic functions. The dominance of cultivated species reflects the importance of home gardens in sustaining ritual practices. Preserving this knowledge is essential for cultural continuity and biodiversity conservation. Strengthening education and community-based initiatives will be key to ensuring its transmission across generations.

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Ethno-ornithology and local ecological knowledge of birds in the agroforestry landscapes of Kalibawang, Central Java, Indonesia

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Abstract. *Nursami F, Ardelia F, Nuraini FL, Aliyazzahra F, Sholiqin M, Iskandar J, Iskandar B, Md Naim D, Setyawan AD. 2025. Ethno-ornithology and local ecological knowledge of birds in the agroforestry landscapes of Kalibawang, Central Java, Indonesia. Asian J Ethnobiol 8: 367-389.* Ethno-ornithological knowledge in rural Java provides important insight into how birds are perceived, classified, utilized, and conserved within agroforestry landscapes. This study documents the structure, transmission, and ecological relevance of Local Ecological Knowledge (LEK) among 124 male respondents from four villages in Kalibawang, Central Java. Bird-related knowledge is transmitted predominantly through patrilineal and male-centered networks, reinforced by mentor–apprentice relationships within *lomba kicau* (songbird competition) culture. Respondents recognized 71 bird species organized into flexible folk categories based on vocalization, habitat association, perceived behavior, symbolic meaning, and management context. Songbirds (*burung kicau*) formed the most dominant and culturally salient category, reflecting the central role of acoustic perception in local cognition. Most recorded species (57.7%) were not directly utilized, indicating that bird exploitation is highly selective rather than pervasive. Active use was concentrated on cage birds and pet trade species, supported by specific capture techniques, particularly bird glue (*getah/pulut*) and netting. Cultural taboos and ethical norms contributed to a substantial proportion of non-captured species, especially forest-dependent and symbolically protected birds. LEK showed strong alignment with scientific knowledge regarding habitat use and conspicuous behavior, while partial mismatches in feeding guild perception were primarily driven by visibility and symbolic interpretation rather than ecological misunderstanding. Culturally salient species, including *Copsychus saularis*, *Pycnonotus aurigaster*, *Zosterops* spp., and *Leptocoma* spp., exhibited high Cultural Importance (CI) values and were closely associated with perceived ecological services such as insect control, pollination, and seed dispersal. Overall, LEK in Kalibawang constitutes a coherent socio-ecological system that integrates cultural values, ecological observation, and informal governance. Despite its gendered and cross-sectional scope, this knowledge system offers a culturally grounded foundation for community-based bird conservation in Javanese agroforestry landscapes.

Keywords: Agroforestry conservation, cultural salience, ethno-ornithology, folk taxonomy, local ecological knowledge

INTRODUCTION

Ethno-ornithology, a branch of ethnobiology, offers a key perspective for understanding human–bird relationships, particularly in regions where birds have ecological, economic, and cultural significance. In Southeast Asia, closely linked forest and agroforest livelihoods give birds diverse roles—as seasonal indicators, trade and food resources, symbols of identity, and objects of aesthetic value. While global research highlights the value of Local Ecological Knowledge (LEK) for community-based conservation and tracking long-term ecological change, studies in Indonesia remain limited despite the country's high endemism and cultural diversity (Şekercioglu 2006; Sodhi et al. 2010). Java is a distinctive setting: one of the world's most densely populated islands, yet still supporting rich avifauna embedded in long-standing cultural practices (Whitten et al. 1996). Evidence from Karangwangi, West Java, Indonesia, shows that rural communities hold detailed, structured LEK—including species recognition and folk classifications based on vocal, morphological, behavioral, and ecological cues—and also reports bird declines linked to habitat loss and hunting (Iskandar et al. 2016). These findings highlight the scarcity of ethno-ornithological research in Java and the need for site-specific studies across varied cultural and ecological contexts.

The agroforestry landscapes of Java have long served as interfaces of human–bird interaction. These multifunctional land-use systems—characterized by mixed fruit trees, bamboo groves, shade vegetation, and homegarden mosaics—offer ecological niches for frugivores, insectivores, and nectarivores alike (Michon and de Foresta 1995; Roshetko

et al. 2007). At the same time, these landscapes are social arenas where bird-related knowledge, beliefs, and practices are negotiated daily. Birds are hunted, trapped, traded, reared for song competitions, or protected due to cultural taboos and spiritual values. The contemporary "kicau culture," which has expanded across Java in recent decades, further shapes people's perceptions and utilization of species such as *Zosterops*, *Pycnonotus*, and *Copsychus*. Consequently, agroforestry zones are not merely ecological habitats but living cultural spaces where LEK is accumulated, contested, and transmitted across generations.

A distinctive feature of Javanese ethno-ornithology is its gendered knowledge system. Ethnographic accounts and field observations indicate that manuk (birds) are strongly associated with men, who dominate trapping, bird-keeping, market trade, and forest-based foraging. Women participate more limitedly, mainly through household care and sharing narrative knowledge, but are less involved in species identification or ecological interpretation. This pattern aligns with wider ethnobiological discussions showing that certain taxa can be culturally coded as masculine domains, shaping access to expertise and decision-making. In Kalibawang, the same pattern appeared across all sampled villages, with men as the main holders and intergenerational transmitters of avian local ecological knowledge (LEK). Recognizing these dynamics is important because transmission pathways influence human–bird interactions and should inform conservation strategies.

Despite birds' ecological and cultural importance in Java, research on bird-related LEK remains scarce. Most studies on Javanese avifauna focus on taxonomy (MacKinnon and Phillipps 1993), ecology/biogeography (van Bemmelen 1949; Whitten et al. 1996), and more recently on conservation crises linked to habitat loss and wildlife trade (Sodhi et al. 2010). Few examine how communities classify birds, transmit knowledge, or how traditional practices align with contemporary ecological science. Consequently, understanding of community-scale human–bird relationships—especially within agroforestry systems—remains limited.

This study addresses these gaps by examining ethno-ornithological knowledge in four villages of Kalibawang, Central Java—Dempel, Karangsambung, Kalialang, and Margolangu—an upland, agroforestry-rich landscape with strong cultural ties to birds. We hypothesize that (i) avian LEK is structured as a hierarchical folk taxonomy based on acoustic, morphological, behavioral, and habitat cues, and (ii) culturally salient species show strong agreement between LEK classifications and scientific ecological guilds and habitat associations. Accordingly, we aim to: (i) document the sources, holders, and distribution of avian LEK; (ii) describe folk taxonomic categories at life-form, generic, and specific levels; (iii) characterize bird-use practices (subsistence, cultural roles, and capture methods); (iv) identify culturally salient species and their symbolic meanings; and (v) assess correspondence between LEK and scientific knowledge, particularly for habitat use, feeding guilds, and conservation status.

MATERIALS AND METHODS

Study area

The study was conducted in October 2024 in four villages of Kalibawang Sub-district, Central Java, Indonesia—Dempel, Karangsambung, Kalialang, and Margolangu—representing different parts of the agroforestry landscape in the southern Serayu Mountains foothills (Figure 1). These upland communities rely on mixed tree gardens and diversified farming systems (e.g., coffee, coconut, mango, bamboo, bananas, and seasonal crops), creating complex vegetation mosaics that support diverse bird communities (Michon and de Foresta 1995; Roshetko et al. 2007; BPS Wonosobo 2023).

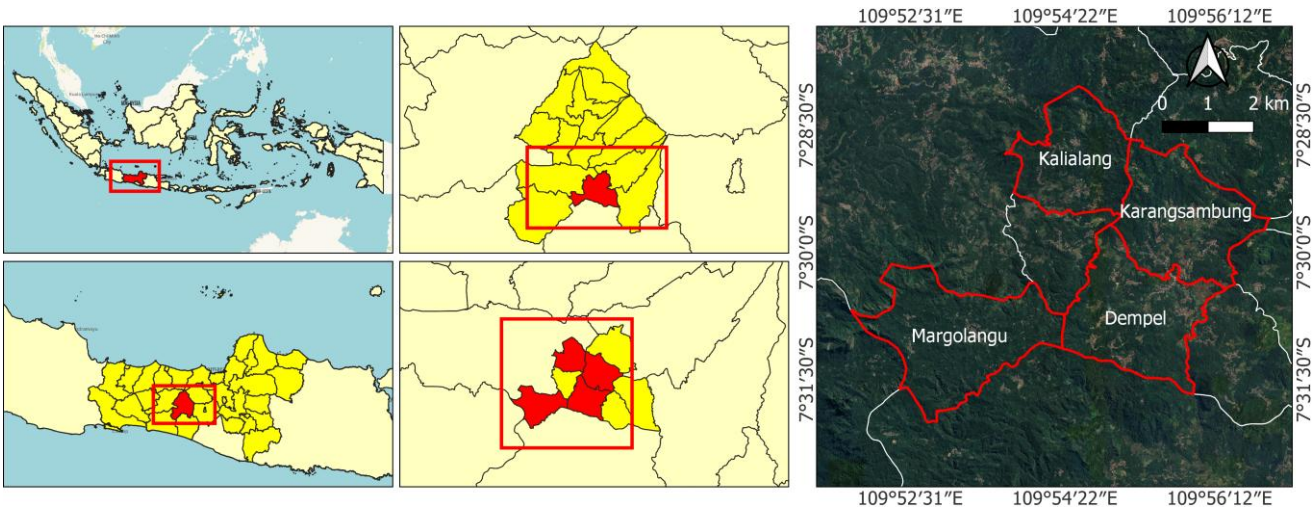

Figure 1. Map of the four study villages (Dempel, Karangsambung, Kalialang, and Margolangu) in the agroforestry landscapes of Kalibawang Sub-district, Wonosobo District, Central Java, Indonesia

The topography is moderately steep, with elevations of 250-550 m above sea level. The area has a tropical monsoonal climate, with a wet season from November to April and a dry season from May to October. Annual rainfall reaches about 2,000-2,500 mm, with average temperatures of 22-28°C and humidity generally above 75% (BMKG 2023). Small rivers and irrigation canals form narrow riparian corridors that connect agroforests with adjacent hillslopes. Although the broader Southern Serayu Mountains landscape has undergone land-use change over the past decades, the agroforestry matrix of Kalibawang remains ecologically important, functioning as a semi-natural buffer zone between settlements, rice fields, and fragmented hill forests. The combination of shaded agroforest, wet-rice paddies, small watercourses, and settlement gardens makes it an ideal setting for examining ethno-ornithological knowledge and human–bird interactions within a culturally embedded agricultural system.

The social–ecological characteristics of Kalibawang further shape human relationships with birds. Most households depend on smallholder agroforestry and paddy agriculture for subsistence, while men actively participate in bird-related practices such as trapping, keeping, and trading. The cultural significance of bird song competitions (*lomba kicau*) is especially prominent, influencing which species are valued, how knowledge is transmitted, and how community members interact with local avifauna. These practices are deeply rooted in Javanese tradition and contribute to the gendered distribution of ecological knowledge observed in this region.

Sampling design and respondent selection

Data collection followed an ethnobiological sampling framework designed to identify individuals who possess extensive and context-specific knowledge of birds within the agroforestry landscapes of Kalibawang. A combined purposive and snowball sampling strategy was employed to reach respondents recognized by the community as "cultural experts," including experienced hunters (*pemburu manuk*), hobbyists involved in bird song competitions, long-term bird keepers, and village elders who have accumulated ecological knowledge through lifelong interaction with agroforests and surrounding forest margins. Purposive sampling enabled the deliberate selection of individuals with specialized knowledge, while snowball sampling allowed respondents to recommend others considered knowledgeable, thereby expanding the network of experts in a culturally grounded manner (Alexiades 1996; Bernard 2017).

A notable characteristic of this study is that all 124 respondents were men, representing an age range from young adults (18-30 years) to older experts (>60 years). This gender distribution is not a sampling bias but a reflection of gendered ecological knowledge in Javanese society, where birds (*manuk*) are culturally coded as a masculine domain. Activities such as trapping, bird-keeping, forest roaming, and participation in *lomba kicau* are overwhelmingly undertaken by men, whereas women rarely engage in species identification, capture practices, or market-related activities. This pattern aligns with broader ethnobiological literature showing that knowledge about certain taxonomic groups—particularly game animals and traded wildlife—is often male-dominated (Pfeiffer and Butz 2005; Jepson and Ladle 2009). Recognizing this gendered context is essential for accurately interpreting how LEK is transmitted and who holds authoritative ecological knowledge within the community.

Interviews, guided walks, and informal discussions were conducted across all four villages, ensuring representation of varied agroforestry contexts and local livelihood backgrounds. Prior to engagement, all respondents were informed of the study objectives, confidentiality procedures, and their right to withdraw from the research at any time. Ethical considerations followed the International Society of Ethnobiology (ISE) (2006) Code of Ethics, including principles of prior informed consent, respect for intellectual sovereignty, and culturally appropriate data handling. This methodological approach ensured that the resulting LEK dataset was both scientifically robust and socially grounded in community-defined expertise.

Ethnobiological interviews and free-listing

Ethno-ornithological data were collected using a combination of semi-structured interviews, free-listing exercises, and in-depth confirmatory interviews to document local knowledge of bird species, habitat associations, and cultural significance. Semi-structured interviews allowed conversations to follow respondents' own narratives while ensuring consistency across participants regarding key themes such as bird names, folk classifications, ecological observations, and historical changes in abundance. This flexible but systematic approach is widely recommended in ethnobiological research because it captures both taxonomic knowledge and contextual cultural meanings (Alexiades 1996; Bernard 2017).

Free-listing was used to elicit the full range of bird taxa known to respondents, including both frequently encountered and rarely observed species. Respondents were asked to spontaneously list all *manuk* they recognized in the agroforestry landscape, enabling the identification of culturally salient species through measures such as frequency of mention, order of recall, and the consistency of naming across villages (Quinlan 2005). This method also helped distinguish between life-form, generic, and specific folk categories, forming the basis for subsequent analysis of folk taxonomy.

To verify the accuracy and depth of recorded knowledge, in-depth interviews were conducted with senior informants—particularly experienced hunters and elders—who were widely regarded as repositories of multigenerational ecological knowledge. These interviews focused on clarifying ambiguous names, validating habitat descriptions, and cross-checking species considered rare or culturally significant. A triangulation approach was employed, comparing statements among multiple experts to ensure the reliability of information and to minimize individual recall bias.

All interviews followed ethical guidelines under the ISE Code of Ethics (2006), including prior informed consent, voluntary participation, and respect for local intellectual property. This combination of interview techniques provided a robust dataset for analyzing how bird knowledge is structured, transmitted, and valued within Kalibawang's agroforestry communities. In total, free-listing and confirmatory interviews resulted in the recognition of 71 bird species across all folk categories in the four study villages.

Folk classification, cultural use, capture techniques, and dominant habitat

Folk ornithological knowledge in Kalibawang was assessed through an integrated analysis of folk classification, cultural utilization, capture techniques, and dominant habitat contexts. Documentation of folk taxonomy followed standard ethnobiological frameworks (Brown 1979; Hunn 1982; Berlin 1992). Birds were grouped into culturally recognized categories based on salient criteria such as vocalization, morphology, behavior, habitat association, and perceived function. Folk categories correspond to life-form and generic levels and include songbirds, rice-field birds, wetland birds, predators, sacred birds, pest birds, settlement-associated birds, and related groups. Consistent with emic classification systems, a species may occur in more than one folk category when justified by cultural meaning or perceived role.

Patterns of bird utilization were analyzed using standardized and mutually exclusive categories derived from local practice. Each species was assigned to a single primary utilization category to avoid overlap, including no direct use, pet bird or cage bird, pet trade, domesticated, occasionally hunted, sacred or culturally protected, edible nest harvested, and ecosystem service (pest control). Although some species have multiple cultural roles, classification was restricted to the dominant use for analytical consistency.

Bird capture techniques were documented and classified into standardized categories, including bird glue trapping (*getah*/*pulut*), netting, snare trapping, cage trapping, projectile hunting, domesticated breeding, nest harvesting, and non-capture due to cultural taboos. Each species was assigned to one dominant capture method based on interview data and field observations, although alternative techniques may be known or occasionally applied. Recorded capture methods reflect traditional practices and do not imply legality.

Dominant habitat was determined based on the primary environment in which each species is most frequently encountered, utilized, or captured according to local knowledge and observation. Habitat categories include agroforestry, forest, forest edge, grassland or open fields, rice fields, settlements, wetlands, riverine areas, and cliffs or rocky habitats. To prevent double-counting, each species was assigned to a single dominant habitat, recognizing that many species occupy multiple habitats ecologically. Habitat classification reflects human–bird interaction contexts rather than exclusive ecological preferences.

Ethnobiological indices (UV, RFC, CI)

To quantify the cultural salience and multidimensional importance of bird species within Kalibawang communities, three widely used ethnobiological indices were calculated: Use Value (UV), Relative Frequency of Citation (RFC), and Cultural Importance Index (CI). These indices provide standardized measures of how frequently and in how many ways a species is recognized, valued, or utilized by local people (Phillips and Gentry 1993; Tardío and Pardo-de-Santayana 2008).

The Use Value (UV) was computed to assess the intensity of cultural knowledge and use associated with each species. UV is defined as:

$$\mathrm{UV} = \frac{\sum U_i}{N}$$

Where, *Ui* represents the number of distinct uses mentioned by each respondent, and *N* is the total number of respondents. Higher UV values indicate species with multiple roles—such as song, symbolism, ecological cues, or economic uses—signifying strong cultural embeddedness.

The Relative Frequency of Citation (RFC) measures how widely known a species is across the community:

$$\mathrm{RFC} = \frac{FC}{N}$$

Where, *FC* is the number of respondents who mention the species. RFC captures species familiarity and general cultural visibility, complementing the more use-oriented UV metric (Tardío and Pardo-de-Santayana 2008).

The Cultural Importance Index (CI) integrates both the diversity of uses and the proportion of informants citing each use category:

$$\mathrm{CI} = \sum_{u=1}^{k} \frac{FC_u}{N}$$

Where, *k* represents the number of use categories. CI is particularly suited for multifunctional taxa, as it reflects both breadth and distribution of knowledge.

These indices were selected because they jointly reveal cultural dependency, knowledge distribution, and species salience, enabling robust interpretation of how birds are valued in the agroforestry-based ethno-ornithological system of Kalibawang.

RESULTS AND DISCUSSION

Socio-cultural profile of respondents and knowledge networks

The 124 respondents interviewed across the four villages of Kalibawang represent a socially diverse yet culturally cohesive community in which bird-related knowledge circulates primarily through male-centered social networks. Most respondents identified their father or grandfather as the earliest and most influential figures who introduced them to bird identification, trapping techniques,

vocal mimicry, and habitat interpretation. This patrilineal pattern reflects the long-standing Javanese norm that birds (*manuk*) are embedded within a masculine cultural domain, where ecological knowledge is transmitted through intergenerational male bonding during farming, forest-edge activities, or shared leisure practices. The centrality of fathers and grandfathers underscores the degree to which LEK is socially inherited rather than independently acquired, forming a stable knowledge base that persists despite environmental change.

Conversely, the role of women in the circulation of bird knowledge was consistently described as minimal or absent. Respondents noted that women rarely participate in trapping, bird keeping, or songbird competitions, and seldom accompany men during agroforest activities where observational learning naturally occurs. This gendered pattern aligns with community norms concerning labor division and symbolic associations between men and bird mastery. As a result, the absence of female participation is not indicative of exclusion but rather reflects a long-standing cultural structure that shapes knowledge accessibility and authority within Kalibawang households.

A distinctive component of knowledge transmission involves mentor–apprentice relationships, particularly among hobbyists engaged in *lomba kicau* (songbird competitions). Younger enthusiasts often learn from more experienced keepers who possess recognized expertise in bird vocalization, diet preparation, conditioning, and species-specific behavior. These learning pathways extend beyond kinship networks, forming horizontal knowledge exchanges that enhance technical specialization and contribute to the diffusion of new techniques, including cage design, lure modification, and acoustic training. Such relationships often transcend village boundaries, supporting a regional knowledge network centered on competitive bird-keeping culture.

Despite shared cultural foundations, knowledge networks show subtle variation across villages. For example, respondents in Karangsambung reported stronger ties to forest-adjacent activities, enabling them to observe a broader range of species and to inherit specialized knowledge related to forest-dwelling taxa. In contrast, Dempel and Kalialang respondents often emphasized knowledge associated with homegardens and rice-field landscapes, reflecting the ecological settings that structure daily encounters with birds. Margolangu displayed a mixed pattern, with both agroforest-influenced and settlement-based knowledge sources.

Table 1 summarizes the distribution of knowledge sources reported by respondents and highlights the predominance of patrilineal and male-centered transmission pathways. The prominence of father-to-son learning, combined with peer apprenticeship networks, illustrates how LEK in Kalibawang is structured through both inheritance and practice-based engagement within agroforestry landscapes.

Folk classification system

The folk classification system documented in Kalibawang reflects a culturally grounded taxonomy in which birds are organized according to locally salient criteria, including vocal characteristics, habitat association, perceived behavior, symbolic meaning, and practical relevance. Based on free-listing and ethnobiological interviews, respondents recognized a set of folk categories that correspond to everyday encounters and cultural interpretations rather than formal scientific taxonomy. As summarized in Table 2, these categories include songbirds, rice-field birds, wetland birds, sacred birds, predators, pest birds, settlement-associated birds, cage birds, game birds, poultry, omen birds, and unclassified species.

Songbirds (*burung kicau*) represent the most dominant folk category, comprising more than half of the recorded species. This category is defined primarily by acoustic qualities, particularly melodious, complex, or trainable vocalizations. Species such as *Copsychus saularis*, *Pycnonotus aurigaster*, *Chloropsis sonnerati*, and *Zosterops* spp. were consistently cited as prototypical songbirds due to their valued calls and suitability for bird keeping or competitions. The prominence of this category highlights the central role of auditory perception in local bird knowledge and reflects the strong influence of songbird culture (*lomba kicau*) in shaping classification criteria.

Rice-field birds (*burung sawah*) form a distinct category associated with open agricultural landscapes, especially paddy fields and field margins. Species included in this group, such as *Mirafra javanica*, *Bubulcus ibis*, *Lonchura leucogastroides*, and *Anthus rufulus* are identified based on frequent encounters during farming activities and their perceived interactions with crops. Classification into this category is closely linked to habitat visibility and seasonal abundance rather than to feeding ecology alone.

Wetland birds (*burung rawa/air*) are recognized as species commonly encountered in marshes, irrigation channels, and flooded fields. Examples include *Amaurornis phoenicurus*, *Gallinula chloropus*, *Porphyrio indicus*, and *Leptoptilos javanicus*. Respondents distinguished these birds primarily by their association with waterlogged habitats and distinctive movement patterns, indicating that spatial context plays a key role in folk categorization.

Table 1. Sources of bird-related knowledge among respondents in Kalibawang Sub-district, Central Java, Indonesia

Source of knowledge	Number of respondents	Percentage (%)
Parents/elders (>30 years)	97	78.22
Friends/peers (≤30 years)	16	12.90
Personal experience	11	8.87
Total	124	100

Note: All respondents (n = 124) were male. This reflects local socio-cultural norms in which bird hunting, bird-keeping, and ecological knowledge of birds are activities primarily practiced by men

Table 2. Folk-based bird categories and associated species in Kalibawang, Central Java, Indonesia

Folk category (English)	Folk category (Indonesia)	No. species	Percentage (%)	Species name
Songbird	*Burung kicau*	41	53.2	*Aegithina tiphia, Aethopyga eximia, Aethopyga siparaja, Anthreptes malacensis, Arachnothera longirostra, Brachypteryx montana crassa, Chloropsis sonnerati, Cinnyris asiaticus, Cinnyris jugularis, Cinnyris solaris, Copsychus malabaricus, Copsychus saularis, Cyanoptila cyanomelana, Cyornis banyumas, Dicaeum trigonostigma, Dicaeum trochileum, Geopelia striata, Gracupica contra, Lanius schach*, Leptocoma calcostetha, Loriculus galgulus, Monticola solitarius, Myophonus glaucinus, Oriolus chinensis, Orthotomus cucullatus, Orthotomus ruficeps, Orthotomus sepium, Orthotomus sutorius, Padda / Lonchura oryzivora, Pericrocotus speciosus, Prinia familiaris, Pycnonotus aurigaster, Pycnonotus goiavier, Pycnonotus simplex, Spilopelia chinensis, Streptopelia risoria, Timalia pileata, Todiramphus chloris, Todiramphus cyanoventris, Zosterops flavus, dan Zosterops palpebrosus*
Rice-field bird	*Burung sawah*	6	7.8	*Mirafra javanica, Bubulcus ibis, Prinia inornata, Lonchura leucogastroides, Anthus rufulus, Acridotheres javanicus*
Wetland bird	*Burung rawa/air*	4	5.2	*Leptoptilos javanicus, Amaurornis phoenicurus, Gallinula chloropus, Porphyrio indicus*
Sacred bird	*Burung mitos/keramat*	3	3.9	*Nisaetus bartelsi*, Surniculus lugubris*, Otus angelinae**
Predator	*Burung pemangsa*	3	3.9	*Lanius schach*, Dicrurus macrocercus*, Otus angelinae**
Pest bird	*Burung hama tanaman*	3	3.9	*Centropus sinensis, Dicrurus macrocercus*, Passer montanus**
Raptor	*Burung pemangsa udara*	2	2.6	*Elanus caeruleus, Nisaetus bartelsi**
Bird of settlement	*Burung permukiman*	2	2.6	*Columba livia, Passer montanus**
Cage bird	*Burung sangkar*	3	3.9	*Serinus canaria domestica, Agapornis sp, Psittacula alexandri*
Game bird	*Burung buruan*	2	2.6	*Gallus gallus bankiva, Gallus varius*
Poultry	*Unggas*	1	1.3	*Columba livia domestica*
Omen	*Burung pertanda*	1	1.3	*Surniculus lugubris**
None	*Tidak diklasifikasikan*	6	7.8	*Collocalia linchi, Collocalia maxima, Corvus enca, Corvus macrorhynchos, Chrysophlegma flavinucha, Dinopium javanense*

Note: This analysis includes 71 unique bird species. The total of 77 folk classification entries reflects six species assigned to multiple categories (*), consistent with emic, community-derived classifications based on cultural meaning and perceived function rather than scientific taxonomy. In the list above, such species are marked with an asterisk. For example, *Passer montanus* is classified both as a rice-field bird and a pest bird, illustrating how a single species can belong to more than one folk category

Several categories are defined primarily by cultural meaning rather than habitat. Sacred birds (*burung mitos/keramat*), such as *Nisaetus bartelsi*, *Otus angelinae*, and *Surniculus lugubris*, are characterized by symbolic attributes, taboo status, or mythological associations. These species are generally avoided and not subjected to capture, illustrating how cultural beliefs directly influence classification and behavior toward birds. Similarly, omen birds (*burung pertanda*), represented by *S. lugubris*, are identified based on perceived associations with misfortune or significant events, demonstrating the role of belief systems in folk taxonomy.

Functional interaction with human activities also shapes classification. Pest birds (*burung hama tanaman*), including *Centropus sinensis* and *Passer montanus*, are identified based on their perceived negative impact on crops, while predator categories encompass birds recognized for hunting behavior or predation on other animals, such as *Elanus caeruleus* and *N. bartelsi*. Settlement-associated birds (*burung permukiman*) are species frequently observed around houses and villages, reflecting patterns of daily human–bird co-occurrence.

Certain categories explicitly reflect management or use contexts, such as cage birds (*burung sangkar*), game birds (*burung buruan*), and poultry (*unggas*). These groups are defined by human intervention, including keeping, hunting, or domestication, rather than by ecological traits alone. In contrast, a small number of species were not assigned to any specific folk category (*tidak diklasifikasikan*), indicating limited cultural salience or ambiguous roles within local knowledge systems.

The folk classification system in Kalibawang is pluralistic and non-exclusive. As shown in Table 2, several species are assigned to more than one folk category, reflecting an emic logic in which classification is shaped by cultural meaning, perceived function, and situational context rather than by rigid taxonomic boundaries. This flexible categorization underscores the dynamic nature of local ecological knowledge and its close integration with daily practices, beliefs, and agroforestry landscapes.

Utilization patterns and capture techniques

Patterns of bird utilization in Kalibawang show that local communities do not directly exploit most recorded species. As summarized in Table 3, more than half of the species (57.7%; 41 species) fall into the category of no direct use, indicating that many birds are primarily perceived as part of the surrounding environment rather than as resources to be actively harvested or managed. These species are typically encountered during daily activities in agroforestry areas, rice fields, wetlands, or forest edges, but are neither intentionally captured nor maintained by local people.

Active utilization is concentrated on a smaller subset of species, mainly those associated with bird keeping and trade. Pet birds or cage birds account for 15.5% of the recorded species, reflecting the strong cultural importance of songbird keeping in Kalibawang. These species are valued primarily for their vocal performance and suitability for captivity. A further 9.9% of species are categorized under the pet trade, indicating targeted capture and exchange of birds with economic value, often driven by demand related to songbird competitions and urban markets. Domesticated species represent 7.0% of the total and consist of birds that are bred and maintained under controlled conditions rather than captured from the wild.

Other forms of utilization occur at much lower frequencies. Occasionally hunted species (4.2%) include birds captured sporadically, mainly for traditional or opportunistic purposes rather than regular consumption. Sacred or culturally protected birds (2.8%) are recognized for their symbolic or spiritual significance and are deliberately avoided, resulting in non-extractive interactions. Highly specific forms of use are represented by single categories, such as edible nest harvesting (1.4%) and ecosystem services in the form of pest control (1.4%), illustrating that these practices are limited to very few species and are not dominant features of local bird utilization.

Table 3. Categories of bird utilization patterns based on local use in Kalibawang, Central Java, Indonesia

Utilization category (English)	Utilization category (Indonesia)	No. species	Percentage (%)	Species name
No direct use	*Tidak dimanfaatkan langsung*	41	57.7	*Aethopyga eximia*, *Aethopyga siparaja*, *Amaurornis phoenicurus*, *Anthreptes malacensis*, *Anthus rufulus*, *Arachnothera longirostra*, *Brachypteryx montana crassa*, *Centropus sinensis*, *Chrysophlegma flavinucha*, *Cinnyris asiaticus*, *Cinnyris jugularis*, *Cinnyris solaris*, *Collocalia linchi*, *Corvus enca*, *Corvus macrorhynchos*, *Cyanoptila cyanomelana*, *Cyornis banyumas*, *Dicaeum trigonostigma*, *Dicaeum trochileum*, *Dicrurus macrocercus*, *Dinopium javanense*, *Elanus caeruleus*, *Leptocoma calcostetha*, *Leptoptilos javanicus*, *Lonchura leucogastroides*, *Monticola solitarius*, *Myophonus glaucinus*, *Oriolus chinensis*, *Orthotomus cucullatus*, *Orthotomus ruficeps*, *Orthotomus sepium*, *Orthotomus sutorius*, *Passer montanus*, *Pericrocotus speciosus*, *Porphyrio indicus*, *Prinia inornata*, *Pycnonotus simplex*, *Surniculus lugubris*, *Timalia pileata*, *Todiramphus chloris*, *Todiramphus cyanoventris*
Pet bird/cage bird	*Burung peliharaan / sangkar*	11	15.5	*Aegithina tiphia*, *Copsychus saularis*, *Geopelia striata*, *Lanius schach*, *Loriculus galgulus*, *Mirafra javanica*, *Prinia familiaris*, *Pycnonotus aurigaster*, *Pycnonotus goiavier*, *Spilopelia chinensis*, *Zosterops palpebrosus*
Pet trade	*Perdagangan burung*	7	9.9	*Acridotheres javanicus*, *Chloropsis sonnerati*, *Copsychus malabaricus*, *Gracupica contra*, *Lonchura oryzivora*, *Psittacula alexandri*, *Zosterops flavus*
Domesticated	*Domestikasi / ternak*	5	7.0	*Agapornis* sp., *Columba livia*, *Columba livia domestica*, *Serinus canaria domestica*, *Streptopelia risoria*
Occasionally hunted	*Diburu sesekali*	3	4.2	*Gallus gallus bankiva*, *Gallus varius*, *Gallinula chloropus*
Sacred / culturally protected	*Sakral / dilindungi secara budaya*	2	2.8	*Nisaetus bartelsi*, *Otus angelinae*
Edible nest harvested	*Pemanenan sarang*	1	1.4	*Collocalia maxima*
Ecosystem service (pest controller)	*Jasa lingkungan (pengendali hama)*	1	1.4	*Bubulcus ibis*

Note: Each bird species was assigned to a single primary human-use category to avoid overlap, although some species have multiple uses. Data were obtained from interviews (N = 124) and field observations, including the use of *getah pulut*, a sticky adhesive made from jackfruit or breadfruit sap applied to twigs or bamboo sticks to trap small birds

Table 4. Standardized methods of bird capture based on local practices

Method of capture (English)	Method of capture (Indonesia)	No. species	Percentage (%)	Species name
Bird glue trapping	*Getah/pulut*	26	36.6	*Aegithina tiphia*, *Aethopyga eximia*, *Aethopyga siparaja*, *Anthreptes malacensis*, *Arachnothera longirostra*, *Chloropsis sonnerati*, *Cinnyris asiaticus*, *Cinnyris jugularis*, *Cinnyris solaris*, *Dicaeum trigonostigma*, *Dicaeum trochileum*, *Lanius schach*, *Leptocoma calcostetha*, *Lonchura oryzivora*, *Orthotomus cucullatus*, *Orthotomus ruficeps*, *Orthotomus sepium*, *Orthotomus sutorius*, *Prinia familiaris*, *Prinia inornata*, *Pycnonotus aurigaster*, *Pycnonotus goiavier*, *Pycnonotus simplex*, *Timalia pileata*, *Zosterops flavus*, *Zosterops palpebrosus*
Netting (mist nets/nets)	*Jaring*	12	16.9	*Brachypteryx montana crassa*, *Columba livia*, *Copsychus malabaricus*, *Copsychus saularis*, *Cyornis banyumas*, *Lonchura leucogastroides*, *Loriculus galgulus*, *Myophonus glaucinus*, *Oriolus chinensis*, *Passer montanus*, *Psittacula alexandri*, *Spilopelia chinensis*
No capture/taboo	*Tidak ditangkap / tabu budaya*	13	18.3	*Chrysophlegma flavinucha*, *Cyanoptila cyanomelana*, *Dicrurus macrocercus*, *Dinopium javanense*, *Elanus caeruleus*, *Leptoptilos javanicus*, *Monticola solitarius*, *Nisaetus bartelsi*, *Otus angelinae*, *Pericrocotus speciosus*, *Surniculus lugubris*, *Todiramphus chloris*, *Todiramphus cyanoventris*
Snare trapping	*jerat*	8	11.3	*Amaurornis phoenicurus*, *Anthus rufulus*, *Centropus sinensis*, *Gallinula chloropus*, *Gallus gallus bankiva*, *Gallus varius*, *Mirafra javanica*, *Porphyrio indicus*
Domesticated breeding	*Domestikasi/ternak*	4	5.6	*Agapornis* sp., *Columba livia domestica*, *Serinus canaria domestica*, *Streptopelia risoria*
Projectile hunting	*Penembakan (senapan angin/ketapel)*	3	4.2	*Bubulcus ibis*, *Corvus enca*, *Corvus macrorhynchos*
Cage trapping	*Perangkap sangkar/bubu*	3	4.2	*Acridotheres javanicus*, *Geopelia striata*, *Gracupica contra*
Nest harvesting	*Pemanenan sarang*	2	2.8	*Collocalia linchi*, *Collocalia maxima*

Note: A total of 71 species (100%) were recorded, with each species assigned to a single dominant capture method for analytical clarity, although multiple techniques may be known or occasionally used in practice; the documented capture methods reflect traditional practices and do not imply legality

Bird capture techniques documented in Kalibawang are similarly uneven in their distribution across species (Table 4). Bird glue trapping (*getah/pulut*) is the most widely applied method, accounting for 36.6% of species. This technique is predominantly used for small to medium-sized passerines and is closely associated with agroforestry settings where birds frequently perch on branches or bamboo stems. Netting (*jaring*), including mist nets and simple nets, represents the second most common method (16.9%) and is applied to species that move along predictable flight paths or forage at lower strata.

A substantial proportion of species (18.3%) are not captured at all due to cultural taboos or deliberate avoidance, particularly those considered sacred, ecologically important, or culturally inappropriate to hunt. Snare trapping (*jerat*) accounts for 11.3% of species and is primarily associated with ground-dwelling or semi-terrestrial birds. Other capture methods occur at lower frequencies, including domesticated breeding (5.6%), projectile hunting using air rifles or slingshots (4.2%), cage trapping (4.2%), and nest harvesting (2.8%).

Bird use in Kalibawang is highly selective and culturally regulated. Only a few species are intensively targeted for keeping or trade using specific capture methods, while most are not used or are protected by cultural norms. As shown in Tables 3 and 4, cultural values, economic interests, and ethical constraints together shape human–bird interactions in this agroforestry landscape.

Alignment between local ecological knowledge and scientific knowledge

To ensure analytical clarity, Table 5 lists selected species for detailed LEK–science comparison, chosen for high cultural salience, well-developed interview narratives, and strong scientific information on ecology or conservation status; species with limited relevance or data were excluded to avoid speculation. Overall, LEK in Kalibawang corresponds closely with scientific knowledge, particularly regarding habitat associations and conspicuous behaviors, especially for frequently encountered and culturally important species (Table 5).

Strong alignment is evident for forest-dependent and culturally protected species. *Nisaetus bartelsi* (Elang Jawa), for example, is locally regarded as a “penjaga alas” (guardian of the forest) and is deliberately avoided by villagers. This perception corresponds well with scientific knowledge identifying the species as an endemic and endangered forest raptor requiring large, intact forest territories. Local practices of avoiding forest clearing near

nesting areas further reinforce this alignment and suggest an implicit form of community-based conservation. Similar congruence is observed for *O. angelinae*, which is culturally protected and scientifically recognized as forest-dependent and sensitive to habitat disturbance.

Culturally salient songbirds also show a high degree of LEK–science convergence. Species such as *Copsychus malabaricus*, *C. saularis*, *P. aurigaster*, and *Zosterops palpebrosus* are valued locally for vocal performance and social behavior. Scientific studies confirm their complex vocal repertoires, territoriality, and, in the case of *Zosterops*, strong flocking tendencies. Local recognition of declining populations in species such as *C. sonnerati* and *Padda oryzivora* is consistent with their documented endangered status and links population decline to trapping pressure and habitat loss.

Alignment is also apparent in habitat-based knowledge. According to Table 6, agroforestry systems represent the dominant habitat context for most recorded species, a pattern that is well recognized by respondents. Local associations of particular species with agroforests, rice fields, wetlands, or forest interiors correspond closely with scientific habitat classifications. For example, rice-field species such as *L. leucogastroides* and *Spilopelia chinensis* are consistently associated with paddy landscapes, while wetland species such as *A. phoenicurus* and *G. chloropus* are linked to flooded fields and marshy areas. These habitat associations demonstrate accurate spatial ecological reasoning derived from repeated daily encounters.

Table 5. Alignment between local ecological knowledge and scientific information for selected bird species in Kalibawang, Central Java, Indonesia

Species name	Local name	Local Ecological Knowledge (LEK)	Scientific knowledge	Alignment/mismatch
Nisaetus bartelsi	Elang Jawa	Considered "penjaga alas" (guardian of forests); never hunted; believed to bring protection	Endemic to Java, endangered, forest raptor requiring a large territory	**Aligned** – habitat and conservation relevance understood by locals
		Locals avoid cutting the forest near nests	Needs an intact forest canopy; sensitive to logging	**Aligned** – supports community-based conservation
Surniculus lugubris	Kedasih	Call signifies misfortune or death; avoided by villagers	Brood parasite cuckoo; known for its melancholic call; not ecologically dangerous	**Partial mismatch** – cultural myth vs. biological neutrality
Copsychus malabaricus	Murai Batu	Excellent songbird; trapped using pulut; high economic value	Known for complex vocal mimicry; overexploited in the bird trade	**Aligned** – locals understand species rarity due to trade
Padda oryzivora	Gelatik Jawa	Rarely seen now, a symbol of Javanese culture	Endemic to Java; endangered due to capture and habitat loss	**Aligned** – local awareness matches scientific decline
Lonchura leucogastroides	Pipit / Bondol	Considered a rice-field pest; hunted during harvest	Primarily granivorous; agricultural pest in Southeast Asia	**Aligned** – perception as pest matches scientific ecology
Gallus gallus bankiva	Ayam Hutan	Used in rituals, cockfighting, and ancestral offerings	Ancestor of the domestic chicken; native to forests and agroforests	**Aligned** – biological and cultural roles consistent
Zosterops palpebrosus	Pleci	Popular singing bird; associated with harmony and togetherness	Known for social flocking behavior and vocal communication	**Aligned** – folk belief reflects ecological behavior
Gracupica contra	Jalak Suren	Believed to bring good luck; mimics human speech	Mimicry confirmed scientifically; now endangered in Java	**Aligned,** but local trade pressure persists
Chloropsis sonnerati	Cucak Ijo	Valued for song; populations are decreasing	Endangered; trapped for the songbird trade; dependent on the forest canopy	**Aligned** – community recognizes decline
Loriculus galgulus	Serindit / Serindit Melayu	Nestlings are sometimes taken from tree hollows	Known cavity nester; vulnerable to nest poaching	**Aligned** – traditional practice impacts conservation

Note*:* Only 10 species are presented because this table focuses on taxa with strong cultural significance, detailed LEK narratives, and well-documented scientific information, allowing robust LEK–science comparison. Other species were excluded due to limited cultural relevance or insufficient comparative data

Table 6. Dominant habitat of birds based on local use in Kalibawang, Central Java, Indonesia

Dominant habitat	No. of species	Percentage (%)	Species names
Agroforestry	30	42.25%	*Aegithina tiphia, Aethopyga eximia, Anthreptes malacensis, Arachnothera longirostra, Centropus sinensis, Chloropsis sonnerati, Cinnyris asiaticus, Cinnyris jugularis, Cinnyris solaris, Copsychus saularis, Dicaeum trigonostigma, Dicaeum trochileum, Dinopium javanense, Geopelia striata, Gracupica contra, Lanius schach, Leptocoma calcostetha, Loriculus galgulus, Oriolus chinensis, Orthotomus ruficeps, Orthotomus sepium, Orthotomus sutorius, Prinia familiaris, Psittacula alexandri, Pycnonotus aurigaster, Pycnonotus goiavier, Pycnonotus simplex, Timalia pileata, Zosterops flavus, Zosterops palpebrosus*
Forest	11	15.49%	*Brachypteryx montana crassa, Chrysophlegma flavinucha, Corvus enca, Cyanoptila cyanomelana, Cyornis banyumas, Gallus varius, Nisaetus bartelsi, Orthotomus cucullatus, Otus angelinae, Pericrocotus speciosus, Surniculus lugubris*
Forest edge	3	4.23%	*Aethopyga siparaja, Copsychus malabaricus, Gallus gallus bankiva*
Grassland / open fields	6	8.45%	*Acridotheres javanicus, Anthus rufulus, Corvus macrorhynchos, Dicrurus macrocercus, Elanus caeruleus, Mirafra javanica*
Rice fields	5	7.04%	*Bubulcus ibis, Lonchura leucogastroides, Lonchura oryzivora, Prinia inornata, Spilopelia chinensis*
Settlements	7	9.86%	*Agapornis* sp.*, Collocalia linchi, Columba livia, Columba livia domestica, Passer montanus, Serinus canaria domestica, Streptopelia risoria*
Wetlands	4	5.63%	*Amaurornis phoenicurus, Gallinula chloropus, Leptoptilos javanicus, Porphyrio indicus*
Riverine	3	4.23%	*Myophonus glaucinus, Todiramphus chloris, Todiramphus cyanoventris*
Cliffs / rocky areas	2	2.82%	*Collocalia maxima, Monticola solitarius*
Total	71	100.00%	

Note: Each species was assigned to one dominant habitat based on local use and observation to avoid double-counting; habitat categories reflect human–bird interaction contexts rather than exclusive ecological preferences

Feeding guild classifications further illustrate areas of convergence and divergence between LEK and scientific knowledge (Table 7). In many cases, local perceptions reflect dominant dietary tendencies, such as the recognition of granivorous species (*Lonchura* spp., *Passer montanus*) and carnivorous raptors (*N. bartelsi*, *Elanus caeruleus*). However, partial mismatches occur where perceptual cues outweigh trophic accuracy. Several insectivorous species observed in rice fields, such as *Dicrurus macrocercus*, are sometimes perceived as crop pests due to their frequent presence during harvest periods, despite scientific evidence that they primarily consume insects and may contribute to pest regulation. These mismatches reflect visibility-based inference rather than a lack of ecological awareness.

Additional divergences are linked to symbolic interpretation rather than ecological misunderstanding. *Surniculus lugubris*, for instance, is widely avoided due to its association with misfortune, while scientific knowledge characterizes the species as a brood-parasitic cuckoo without harmful ecological effects. Such cases represent cultural overlays on ecological knowledge rather than direct contradictions and highlight the role of belief systems in shaping LEK.

LEK in Kalibawang largely aligns with scientific ornithological knowledge, especially regarding habitat use, conspicuous behavior, and culturally important species. Any mismatches mainly reflect perceptual salience, symbolic meanings, or context-dependent interpretations rather than major ecological errors. This highlights LEK as a valuable complementary information source for understanding human–bird interactions in agroforestry landscapes.

Culturally salient bird species

Culturally salient birds in Kalibawang are frequently cited for their aesthetic value, symbolic meaning, direct use, or perceived population trends. Table 8 highlights twelve prominent species that play key roles in local practices, beliefs, and management—through bird keeping and trade, ritual use, avoidance norms, and conservation awareness.

Songbirds with high aesthetic and economic value dominate this group. *Copsychus saularis* and *C. malabaricus* are consistently highlighted as prestigious birds for songbird competitions (*lomba burung*), valued for strong, complex, and aggressive vocal performances. These species are actively kept or traded and command high market prices, particularly *C. malabaricus*, which is widely recognized by locals as increasingly rare due to intensive trapping. Similarly, *C. sonnerati* and *Gracupica contra* are culturally associated with wealth, prestige, and vocal mimicry, and respondents frequently noted declining encounters with these species in the wild, aligning with their protected and endangered status.

Several culturally salient species are valued primarily as cage birds rather than commercial commodities. *Geopelia striata*, *Z. palpebrosus*, *Loriculus galgulus*, and *C. saularis* are commonly kept for companionship, soundscape enrichment, and aesthetic enjoyment. In particular, *Z. palpebrosus* has gained prominence through the recent "pleci mania" trend, while *L. galgulus* is appreciated for its coloration and soft calls. These species are generally perceived as approachable and easy to maintain, reinforcing their popularity among household bird keepers.

Cultural salience in Kalibawang is not limited to use; some species are prominent because they are protected or avoided. *Nisaetus bartelsi* is viewed as a sacred forest

guardian (*penjaga alas*), so people intentionally avoid hunting or disturbing it. *Surniculus lugubris* is associated with misfortune or death; although not used, its call is considered taboo and strongly influences local behavior toward the species.

Table 7. Feeding guild of birds based on local use in Kalibawang, Central Java, Indonesia

Feeding guild	No. of species	Percentage (%)	Species names
Insectivore	27	38.03%	*Aegithina tiphia, Anthus rufulus, Brachypteryx montana crassa, Bubulcus ibis, Centropus sinensis, Chrysophlegma flavinucha, Collocalia linchi, Collocalia maxima, Copsychus malabaricus, Copsychus saularis, Cyanoptila cyanomelana, Cyornis banyumas, Dicrurus macrocercus, Dinopium javanense, Lanius schach, Mirafra javanica, Monticola solitarius, Myophonus glaucinus, Orthotomus cucullatus, Orthotomus ruficeps, Orthotomus sepium, Orthotomus sutorius, Pericrocotus speciosus, Prinia familiaris, Prinia inornata, Surniculus lugubris, Timalia pileata*
Omnivore	8	11.27%	*Acridotheres javanicus, Amaurornis phoenicurus, Corvus enca, Corvus macrorhynchos, Gallinula chloropus, Gallus gallus bankiva, Gallus varius, Gracupica contra*
Granivore	7	9.86%	*Agapornis* sp., *Columba livia, Geopelia striata, Lonchura leucogastroides, Lonchura oryzivora, Passer montanus, Spilopelia chinensis*
Nectarivore	7	9.86%	*Aethopyga eximia, Aethopyga siparaja, Anthreptes malacensis, Cinnyris asiaticus, Cinnyris jugularis, Cinnyris solaris, Leptocoma calcostetha*
Carnivore	5	7.04%	*Elanus caeruleus, Nisaetus bartelsi, Otus angelinae, Todiramphus chloris, Todiramphus cyanoventris*
Frugivore–Insectivore	4	5.63%	*Chloropsis sonnerati, Oriolus chinensis, Pycnonotus aurigaster, Pycnonotus goiavier*
Frugivore	3	4.23%	*Loriculus galgulus, Psittacula alexandri, Pycnonotus simplex*
Nectarivore–Insectivore	3	4.23%	*Arachnothera longirostra, Zosterops flavus, Zosterops palpebrosus*
Domesticated	3	4.23%	*Columba livia domestica, Serinus canaria domestica, Streptopelia risoria*
Frugivore–Nectarivore	2	2.82%	*Dicaeum trigonostigma, Dicaeum trochileum*
Herbivore	1	1.41%	*Porphyrio indicus*
Scavenger	1	1.41%	*Leptoptilos javanicus*
Total	71	100%	

Note: Each species was assigned to one primary feeding guild based on dominant dietary traits to avoid double-counting; guild categories represent general feeding tendencies rather than exclusive or quantitative diets

Table 8. Culturally significant bird species and their perceived ecological roles in Kalibawang, Central Java, Indonesia

Scientific name	Cultural role/meaning	Utilization type	Conservation/ legal status	Notes from local knowledge
Copsychus malabaricus	Prestigious songbird for contests (lomba burung)	Pet trade	Protected (Permen LHK), LC, CITES II	High market price; trapped using pulut or mist nets
Chloropsis sonnerati	Symbol of wealth, high aesthetic value	Pet trade	EN, Protected	Populations are declining; locals say "susah ditemui di alam."
Geopelia striata	Brings tranquility, spiritual harmony	Pet bird / cage bird	Not protected, LC	Believed to bring fortune to households
Nisaetus bartelsi	Sacred forest guardian; omen of protection	Sacred / culturally protected	EN, Protected, CITES II	Locals avoid hunting; called "penjaga alas."
Surniculus lugubris	Believed to predict death or misfortune	No direct use	LC	Its call is taboo to mimic; associated with sorrow
Gallus gallus bankiva	Ritual sacrifices, ancestor offerings	Occasionally hunted	LC, Protected	Used in selametan and traditional rituals
Lonchura leucogastroides	Considered rice pest (hama padi)	No direct use	LC	Trapped using jaring; children hunt with slingshots
Padda oryzivora	Formerly abundant, now rare; cultural icon	Pet trade	EN, Protected	Associated with the rural identity of Java
Zosterops palpebrosus	Popular cage bird, "pleci mania" culture	Pet bird / cage bird	LC	Kept for group singing (ngerumpi), easy to trap
Gracupica contra	Prestige bird; mimics human speech	Pet trade	EN, Protected	Populations are dropping; only a few are spotted in the field
Loriculus galgulus	Kept for beauty and unique soft calls	Pet bird / cage bird	LC, CITES II	Traded locally; nestlings sometimes taken from trees
Copsychus saularis	Songbird in competitions; symbol of virility	Pet bird / cage bird	LC	Valued for aggressive singing style ("tarung gaya")

Note: These 12 species were selected because they represent birds with the highest cultural relevance, direct human use (pet, ritual, trade, pest control), legal or conservation concern, or were reported by locals as declining in the wild

Other species are salient due to their roles in ritual or subsistence-related contexts. *Gallus gallus bankiva* is occasionally hunted and used in traditional rituals, such as *selametan* and ancestral offerings, reflecting its cultural importance despite limited frequency of use. In contrast, *L. leucogastroides* is culturally recognized as a rice-field pest (*hama padi*); although not intensively exploited, its presence during harvest periods makes it salient in agricultural narratives and childhood hunting practices.

Finally, some species are emphasized because of their symbolic and historical significance. *Padda oryzivora*, once abundant and now rarely observed, is widely regarded as a cultural icon of rural Java. Respondents frequently linked its decline to trapping pressure and habitat change, demonstrating local awareness of conservation issues consistent with its endangered status.

Culturally salient birds in Kalibawang reflect diverse relationships—from trade and recreational keeping to symbolic protection and cultural avoidance. Their prominence arises from the overlap of cultural values, livelihoods, and conservation perceptions, showing how local knowledge highlights certain taxa and shapes human–bird interactions in agroforestry landscapes.

Ethnobiological indices (UV, RFC, CI)

Patterns derived from ethnobiological indices—Use Value (UV), Relative Frequency of Citation (RFC), and Cultural Importance (CI)—offer quantitative insight into how bird species are embedded within the socio-cultural and ecological fabric of Kalibawang. Although full numerical outputs are presented in Table S2, several clear trends emerge from the analysis, particularly regarding the top ten species with the highest CI scores. Species that dominate multiple dimensions of cultural relevance include *P. aurigaster*, *C. saularis*, *Zosterops* spp., *C. sonnerati*, *Leptocoma* spp., and a small number of forest-edge insectivores such as *D. macrocercus*. These species appear at the intersection of high visibility, frequent acoustic presence, ease of recognition, and functional roles within agroforestry systems.

Among these, *P. aurigaster* and *C. saularis* consistently exhibited the highest RFC values, reflecting the fact that nearly all respondents mentioned them spontaneously in free-listing exercises. Their ubiquity in agroforestry soundscapes and homegardens makes them cognitively accessible, while their long-standing cultural resonance ensures intergenerational transmission of knowledge. High UV values for these species indicate the breadth of their uses—from recreational keeping and vocal training to symbolic associations and, historically, occasional roles in ritual contexts. Their enduring familiarity explains why they anchor the cognitive structure of Kalibawang's folk ornithology.

The broad distribution of *Zosterops* and *Leptocoma* species across gardens, flowering shrubs, and semi-open agroforest zones also contributes to their elevated CI. Respondents frequently attributed ecological functions to these taxa: pleci (*Zosterops*) as indicators of flowering periods and landscape productivity, and sunbirds (*Leptocoma*) as pollinators whose presence signals healthy homegarden ecosystems. These functional interpretations align with scientific guild classifications, explaining the strong alignment between LEK and ecology-based indices discussed earlier.

The combined behavior of UV, RFC, and CI illustrates not only species salience but also social–ecological dependency: species that are repeatedly encountered, economically relevant, acoustically valued, or symbolically meaningful naturally occupy central positions in local knowledge networks. Conversely, species with low CI scores tend to be either cryptic, transient, difficult to trap, or lacking significance in songbird culture.

Overall, ethnobiological indices reveal a coherent hierarchy of cultural importance, where daily familiarity, ecological function, and aesthetic value intersect to define which birds matter most to agroforestry communities. Numerical details for all species are available in Table S1.

Discussion

Transmission of bird knowledge in the Javanese agroforestry society

The transmission of bird-related knowledge in Kalibawang reflects a deeply rooted patrilineal structure, shaped by cultural norms, labor division, and the historical role of men in agroforestry management. Consistent with Table 1, the majority of the 124 respondents across four villages identified fathers, grandfathers, and older male mentors as their primary sources of bird-related knowledge, a pattern that aligns with ethnobiological observations in rural Southeast Asia where ecological knowledge is strongly gendered (Pfeiffer and Butz 2005; Jepson and Ladle 2009). In Javanese society, manuk (birds) have long been embedded within masculine domains of expertise—hunting, forest roaming, bird keeping, competitive songbird training, and participation in local markets. This cultural framing regulates who has access to experiential learning opportunities and who becomes recognized as a knowledge authority within the community.

Comparative studies across Indonesia reinforce this pattern. In Bali, Sulawesi, and the Lesser Sunda Islands, bird hunting and bird keeping are overwhelmingly practiced by men, resulting in male-dominated knowledge transmission systems (e.g., Katuwal et al. 2021; Plieninger et al. 2025). Similarly, ethnobiological studies among Sundanese and Madurese communities show that women rarely participate in bird-related activities except in supportive roles such as cage cleaning or preparing feed. As documented in Kalibawang, this limited female involvement reflects culturally structured divisions of labor rather than explicit exclusion, resonating with broader global literature on gendered ecological knowledge where mobile wildlife taxa are typically associated with male expertise (Howard 2003; Reyes-García et al. 2009). In Kalibawang, such patterns are reinforced through daily socialization: boys accompany their fathers to agroforest margins, learn to recognize calls, practice setting traps, and gradually build competency in both folk taxonomy and bird behavior interpretation.

The patrilineal structure is further sustained by the cultural prominence of *kicau* (songbird) activities, which

function not only as recreation but also as a form of social capital among men. Participation in lomba *kicau* requires mastery of species identification, vocal variation, conditioning techniques, and ecological cues—skills that are rarely transmitted to daughters or female relatives. Table 1 show that mentor–apprentice relationships among hobbyists constitute an important secondary pathway of knowledge transmission, extending beyond kinship ties. Such networks are characteristic of Indonesian songbird culture, where knowledge circulates through informal peer groups, competition teams, and local market interactions. Studies from Java and Sumatra indicate that these networks act as powerful learning institutions, shaping species preference, trapping pressure, and valuation systems (Chng and Eaton 2016; Marshall et al. 2020). In Kalibawang, these mechanisms explain why younger men increasingly acquire expertise not only from family members but also from experienced bird keepers, thereby diversifying local knowledge channels.

Despite its gendered character, LEK in Kalibawang remains highly adaptive. Respondents reported the incorporation of new learning media, including digital song recordings, acoustic analysis, and online tutorials, reflecting broader transformations in contemporary Indonesian songbird cultures. This adaptive exchange supports the persistence of detailed ecological understanding even as trapping practices and competition standards evolve. Importantly, while most knowledge transmission remains oral and practice-based, the Results demonstrate a high degree of internal consistency in folk taxonomy across villages, indicating strong cultural coherence maintained through repeated observation and shared practice.

Regional comparisons further suggest that Javanese agroforestry landscapes—characterized by mixed fruit gardens, bamboo groves, rice fields, and forest-edge habitats—provide particularly favorable conditions for bird knowledge acquisition. As shown in Table 1, village-level variation in knowledge emphasis corresponds closely with dominant local habitats, with forest-adjacent communities reporting greater familiarity with forest taxa and settlement-based villages emphasizing garden and agricultural species. Such patterns parallel findings from Amazonian and Melanesian contexts, where early and continuous exposure to diverse soundscapes and habitats underpins the development of detailed ornithological knowledge (Berlin 1992; Hunn 2002).

The patrilineal, practice-based, and competition-influenced structure of knowledge transmission in Kalibawang mirrors broader Southeast Asian patterns while retaining distinctively Javanese cultural features. These transmission pathways directly shape which species become culturally salient, how folk classifications are reinforced, and how communities interpret ecological change, providing an essential foundation for understanding human–bird interactions in agroforestry landscapes.

Folk taxonomy and cultural cognition

The folk classification system documented in Kalibawang reflects core cognitive principles widely recognized in ethnobiology, particularly the hierarchical organization of living organisms as described by Brown (1979), Hunn (1982), and Berlin (1992). At the broadest level, respondents recognize a general life-form category equivalent to birds (*manuk*), encompassing all volant vertebrates perceived as avifauna. This life-form category functions as a broad cognitive umbrella rather than a taxonomic unit in the scientific sense. Below this level, birds are organized into a series of culturally meaningful folk categories that correspond to everyday experience, habitat association, symbolic meaning, and practical relevance rather than to formal scientific taxonomy. These categories, summarized in Table 2, include songbirds, rice-field birds, wetland birds, predators, sacred birds, pest birds, settlement-associated birds, game birds, poultry, omen birds, and unclassified species.

Among these, songbirds (*burung kicau*) constitute the most cognitively dominant category, both in terms of species richness and cultural salience. Classification into this group is primarily based on acoustic qualities, particularly melodious, complex, or distinctive vocalizations. Species such as *C. saularis*, *P. aurigaster*, *C. sonnerati*, and *Zosterops* spp. are consistently recognized as prototypical members of this category. The prominence of songbirds reflects the central role of auditory perception in local bird knowledge and the strong influence of songbird keeping and competitive bird contests (*lomba kicau*) on cognitive categorization. Similar sound-based folk groupings have been reported in other Javanese and Sundanese communities, where vocal performance strongly shapes aesthetic and economic valuation of birds (Iskandar et al. 2016).

Habitat-based cognition also plays a major role in structuring folk taxonomy. Rice-field birds (*burung sawah*) and wetland birds (*burung rawa/air*) are defined largely by spatial context and patterns of encounter during agricultural activities. Species associated with paddy fields, irrigation canals, and flooded areas are grouped according to frequent visibility in these environments rather than strict dietary criteria. This spatially grounded classification illustrates how daily livelihood activities—particularly farming—shape perceptual salience and taxonomic grouping, a pattern widely observed in agrarian societies across Southeast Asia.

Several folk categories are primarily defined by cultural meaning and symbolic interpretation rather than ecological traits. Sacred birds (*burung mitos/keramat*), such as *N. bartelsi* and *O. angelinae*, are characterized by taboo status, mythological associations, or perceived spiritual roles, resulting in deliberate avoidance and non-capture. Similarly, omen birds (*burung pertanda*), represented by *S. lugubris*, are classified based on their perceived ability to signal misfortune or significant events. These categories illustrate that belief systems are not peripheral but integral components of folk taxonomic reasoning, influencing both classification and human behavior toward birds.

Functional interaction with human activities further shapes cognitive categorization. Pest birds (*burung hama tanaman*) are identified based on perceived negative impacts on crops, while predator categories include species recognized for hunting behavior or predation. Settlement-associated birds (*burung permukiman*) are grouped according to frequent co-occurrence with humans in residential areas, reflecting patterns of everyday familiarity. Other categories, such as cage birds, game birds, and poultry, are explicitly defined by modes of management, including keeping, hunting, or domestication, underscoring the role of human intervention in shaping folk taxonomic boundaries.

Importantly, the folk taxonomy of Kalibawang is non-exclusive and context dependent. As shown in Table 2, several species are assigned to more than one folk category, reflecting an emic logic in which classification varies according to situation, function, and cultural meaning. For example, a species may simultaneously be recognized as a rice-field bird and a pest bird, or as a songbird and a settlement-associated species. This flexibility is consistent with Hunn's (1982) concept of cultural elaboration, whereby species of high cultural relevance receive more detailed and context-sensitive classification than ecologically marginal taxa.

The degree of correspondence between folk taxonomy and scientific ecology is generally high, particularly with respect to habitat association and conspicuous behavioral traits. However, divergences occur when perceptual salience overrides trophic accuracy, such as when insectivorous species observed in rice fields are perceived as crop pests. These patterns echo findings from other agrarian landscapes, where proximity to crops strongly influences local interpretations of bird behavior (Ntiamoa-Baidu 1995). Rather than indicating misinterpretation, such divergences reflect pragmatic, interaction-based ecological reasoning grounded in everyday experience.

The folk taxonomy of Kalibawang demonstrates a cognitively efficient and culturally embedded system that integrates perceptual cues, functional relationships, and symbolic meaning. This hybrid structure reinforces the analytical value of local ecological knowledge for understanding human–bird interactions in agroforestry landscapes and provides an essential interpretive bridge between cultural cognition and ecological processes.

Dynamics of bird utilization: subsistence, ritual, market, and hobby

Patterns of bird utilization in Kalibawang demonstrate a clear shift from historically diverse forms of interaction toward increasingly selective, culturally mediated use. As shown in Table 3, the majority of recorded bird species (57.7%) are currently not directly utilized, indicating that most birds are perceived primarily as elements of the surrounding agroforestry landscape rather than as consumable resources. This pattern contrasts with earlier subsistence-oriented practices recalled by older respondents, in which small granivorous species, particularly *L. leucogastroides* and related taxa, were occasionally harvested during rice harvest periods, mainly as opportunistic or childhood hunting activities rather than as a primary protein source. Comparable low-intensity subsistence use has been reported from other rural parts of Java and eastern Indonesia (Wadley et al. 1997; Riley 2002).

In contemporary Kalibawang, direct consumption of birds is rare and confined to a very small subset of species categorized as "occasionally hunted" (4.2%; Table 3), such as *G. g. bankiva* and *Gallus varius*. Respondents commonly described bird consumption as outdated, unnecessary, or culturally marginal, attributing its decline to improved food availability, changing dietary norms, and growing awareness of wildlife protection. This pattern mirrors transitions documented in Karangwangi and other Javanese agroforestry communities, where bird use has shifted away from subsistence necessity toward symbolic, recreational, or economic motivations (Iskandar and Iskandar 2015).

Ritual and symbolic uses have likewise diminished in practical importance. Results indicate that ritual use is now limited to a very small number of species and is largely embedded within cultural memory rather than active practice. Older respondents recalled symbolic associations, such as interpreting the presence of *P. aurigaster* as a sign of household harmony or associating the calls of *S. lugubris* with misfortune. While such beliefs persist, Table 3 shows that species linked to ritual or symbolic meaning are currently classified either as "no direct use" or "sacred/culturally protected," rather than as actively exploited taxa. This pattern suggests a broader secularization of ecological symbolism, consistent with trends reported among Javanese and Sundanese communities (Geertz 1960; Ekowati et al. 2024).

The most pronounced transformation in bird utilization is the rise of market-oriented and hobby-driven practices. According to Table 3, pet birds and pet trade together account for more than one-quarter of all utilized species (25.4%), reflecting the strong influence of songbird culture and urban market demand. Species such as *C. saularis*, *C. malabaricus*, *C. sonnerati*, *Z. palpebrosus*, and *Gracupica contra* have acquired heightened cultural and economic value due to their vocal performance, aesthetic traits, and prestige within lomba kicau networks. These findings are consistent with studies showing that Indonesian bird markets and competition circuits shape species preference and intensify selective trapping (Jepson and Ladle 2005; Chng and Eaton 2016; Marshall et al. 2020).

Results from Table 4 further demonstrate that capture techniques are closely aligned with utilization type, with bird glue trapping (*getah*/*pulut*) and netting (*jaring*) dominating methods used for songbirds and trade-targeted species. Hobby-driven capture is highly selective, focusing on individuals with desirable vocal traits rather than indiscriminate harvesting. Mentor–apprentice networks among hobbyists facilitate the transmission of species-specific knowledge related to song quality, conditioning, and capture techniques, reinforcing both cultural cohesion and trapping pressure on favored taxa. Similar dynamics have been documented in Java and Sumatra, where hobby culture reshapes ecological knowledge and contributes to

population declines of heavily targeted species (Harris et al. 2015; Leupen et al. 2020).

Despite increasing commercialization, local ethical norms continue to regulate bird capture and use, albeit unevenly. Respondents frequently referred to aturan ndaru, an unwritten customary rule discouraging capture during nesting periods. This ethic is reflected in Table 4 by the relatively high proportion of species classified as "not captured/taboo" (18.3%), particularly forest-dependent and culturally protected birds such as *N. bartelsi* and *O. angelinae*. While adherence to these norms varies across households and age groups, their persistence indicates that moral considerations still play a role in moderating exploitation, even in the absence of formal enforcement.

Collectively, the Results support a trajectory of change in Kalibawang characterized not by linear replacement, but by selective retention and reconfiguration of bird use. Subsistence and ritual practices have largely receded, while market and hobby-based interactions now dominate extractive use, alongside a broad category of species that remain culturally recognized yet non-utilized. This pattern underscores that bird utilization in Kalibawang is not intensive overall, but highly selective, culturally framed, and mediated by economic opportunity and ethical constraints. These dynamics parallel broader patterns observed in other Javanese agroforestry landscapes and highlight the need for conservation approaches that engage with hobby culture, market demand, and local moral frameworks rather than focusing solely on subsistence hunting reduction.

Cultural salience, guilds, and ecological services

Cultural salience of birds in Kalibawang emerges from the interaction between perceptual prominence (acoustic and visual traits), frequency of encounter, and perceived ecological function within agroforestry landscapes. Species characterized by conspicuous vocalizations or striking plumage—such as *C. saularis*, *Zosterops* spp., and *C. sonnerati*—were consistently identified in the results (Table 8) as culturally prominent taxa. These species are not only aesthetically valued but also highly visible and audible in daily agroforestry activities, reinforcing their cognitive salience. Similar links between perceptual cues and cultural valuation have been widely documented in ethnobiological studies across tropical regions (Berlin 1992; Atran 1990; Hunn 1999).

Local interpretations of bird ecology closely parallel scientific feeding guild classifications. As summarized in Table 7, insectivorous birds constitute the dominant guild (38.03%), and many of these species—such as *C. saularis*, *D. macrocercus*, *Orthotomus* spp., and *Prinia* spp.—are widely perceived as beneficial components of agroforestry systems. Respondents frequently associated these birds with reduced insect abundance in rice fields, homegardens, and mixed-crop plots. Although such benefits are expressed in non-technical terms, they correspond well with ecological evidence demonstrating the role of insectivorous birds in pest regulation within tropical agricultural mosaics (Şekercioglu 2006; Maas et al. 2015).

Nectarivorous and frugivorous guilds are likewise recognized through seasonal and habitat-based observation. Nectarivores, including *Leptocoma* spp. and *Cinnyris* spp., were commonly linked to flowering trees and shrubs in agroforestry and settlement environments (Table 6), while frugivores and frugivore–insectivores such as *P. aurigaster*, *Oriolus chinensis*, and *Zosterops* spp. were associated with fruiting cycles and vegetation regeneration. These observations align with established ecological roles of birds as pollinators and seed dispersers in tropical agroforestry systems (Kissling et al. 2007; Karp et al. 2013). Thus, cultural recognition of these species is grounded not only in aesthetics but also in repeated empirical observation of ecological processes.

The correspondence between folk categories and scientific guilds reflects a vernacular "folk guild" system, in which birds are grouped according to perceived function and behavior rather than taxonomic affinity. Songbirds (burung kicau), which dominate local classification (Table 2), overlap strongly with insectivorous, nectarivorous, and frugivore–insectivore guilds that are acoustically active and visually conspicuous. This pattern supports broader ethnobiological findings that folk taxonomies often converge with functional ecological groupings, particularly in communities with frequent, multisensory interaction with wildlife (Hamzah et al. 2023).

Landscape context further reinforces this alignment. As shown in Table 6, agroforestry habitats account for the largest proportion of recorded species (42.25%), followed by forest, settlement, and rice-field environments. This heterogeneous mosaic provides continuous opportunities for observing bird foraging, movement, and habitat use, allowing ecological knowledge to be built through direct experience rather than abstract inference. The dominance of agroforestry-associated species among culturally salient birds highlights the importance of multifunctional landscapes in sustaining both ecological processes and local knowledge systems.

The results demonstrate that cultural salience in Kalibawang is closely intertwined with feeding guild structure and perceived ecological services. Birds are valued not only for their aesthetic and acoustic qualities but also for their functional roles in agroforestry systems, particularly insect control, pollination, and seed dispersal. This convergence between cultural valuation and ecological function underscores the analytical strength of LEK and supports its relevance for conservation and landscape management in human-dominated tropical environments.

Taken together, the alignment between cultural valuation and ecological function underscores the depth of ecological understanding embedded within Kalibawang's LEK system. Birds are appreciated not only for their aesthetic and acoustic qualities but also for the ecological services they provide to agroforestry systems. This synergy highlights the potential of integrating LEK into conservation planning, particularly in multifunctional landscapes where ecological processes and cultural traditions are mutually reinforcing.

Taken together, these culturally grounded perceptions of ecological function and aesthetic value demonstrate how local knowledge systems actively shape community attitudes toward bird protection. Such intertwined cultural–ecological logics naturally extend into the realm of conservation practice, providing the socio-cultural basis for the management implications discussed in the next section.

Implications for conservation and community-based management

The strong cultural attachment to certain bird species in Kalibawang provides a distinctive foundation for conservation initiatives that resonate with local values and everyday experience. Species with high aesthetic, acoustic, or symbolic significance—such as *C. saularis*, *P. aurigaster*, and *Zosterops* spp.—are more readily subject to informal attention, selective care, or cultural avoidance by residents because they contribute to household identity, community pride, and the familiar soundscape of agroforestry gardens. This pattern parallels findings from other Indonesian and Southeast Asian contexts, where culturally salient species receive varying degrees of informal consideration or protection, even in the absence of formal regulation (Jepson and Ladle 2009; Reyes-García et al. 2013). In Kalibawang, the alignment between cultural valuation and ecological importance creates social conditions that may support conservation-oriented behavior, making protective practices meaningful and locally legitimate.

An important consideration emerging from the documented capture practices (Table 4) concerns their legal status under national wildlife regulations. Several methods recorded in Kalibawang, such as bird glue trapping (*getah*/*pulut*), netting, and nest harvesting, are widely recognized as traditional techniques but may intersect with current conservation laws when applied to protected species or conducted within restricted habitats. Importantly, this study documents these practices as elements of local ecological knowledge and cultural tradition, rather than as an assessment of legal compliance. Legal implications, therefore, depend on species status, spatial context, and scale of use. The coexistence of traditional capture methods and formal conservation regulations highlights a potential gap between statutory frameworks and local practice, underscoring the need for culturally informed outreach, clarification of legal boundaries, and participatory approaches that align conservation objectives with community norms.

Community institutions further shape the social dynamics underlying bird conservation. Village elders, songbird specialists, and leaders of *kicau* groups serve as influential knowledge brokers who mediate norms surrounding trapping, captive care, and ethical conduct. As indicated in the Results, their influence is expressed mainly through advice, customary restraint, and peer regulation rather than formal enforcement. Their endorsement of sustainable behaviors—such as discouraging capture during nesting seasons or favoring captive maintenance over wild capture—plays a role in reinforcing local stewardship. These forms of social authority function similarly to semi-formal governance structures documented elsewhere in Java, where hobby networks and community leaders often exert strong influence over conservation outcomes. Comparable insights arise from Cijambu, West Java, where shifting cultural motivations, local leadership, and evolving norms regulate hunting intensity and species selection, demonstrating that conservation effectiveness is contingent upon localized socio-cultural configurations rather than ecological considerations alone (Suroso et al. 2023). Parallel patterns are also evident in Semarang's traditional markets, where consumer preferences, traders' knowledge systems, and informal ethical norms shape which species are harvested, traded, or avoided, illustrating that market-based socio-cultural dynamics must also be integrated into conservation planning (Azizah et al. 2025).

Urban ethno-ornithological studies likewise highlight the need for culturally anchored strategies. Research from Bandung shows that songbird contests—while enhancing public knowledge of bird care, vocal performance, and breeding—can inadvertently intensify harvesting pressure when left unmanaged (Iskandar and Iskandar 2015). Expanding competition circuits increase demand for wild-caught individuals, demonstrating how culturally valued practices may undermine conservation goals unless supported by governance innovations such as certification of captive-bred birds, ring-marking systems, and community oversight. Although such mechanisms are not yet formalized in Kalibawang, these insights offer practical relevance: integrating similar approaches through *kicau* groups and village leadership could reduce market-driven exploitation while preserving culturally meaningful traditions.

Given these socio-cultural dynamics, conservation strategies in Kalibawang are likely to be most effective when they integrate local logic with ecological objectives. Potential interventions include (i) community agreements regulating trapping intensity and discouraging capture during breeding seasons, (ii) promoting culturally valued but non-threatened species within hobby networks to reduce pressure on vulnerable taxa, (iii) involving *kicau* leaders and respected elders in participatory observation of forest-edge and agroforestry species, and (iv) designing educational initiatives grounded in local terminology, folk categories, and documented Local Ecological Knowledge. Such strategies leverage existing cultural frameworks, ensuring that conservation messages are intelligible, locally relevant, and mediated by trusted social actors.

Ultimately, community-based management in Kalibawang can function synergistically with ecological science when it acknowledges the cultural, economic, and ethical motivations shaping human–bird interactions. By aligning conservation initiatives with cultural salience, local authority structures, and daily agroforestry experience, these approaches support both biodiversity persistence and cultural continuity, fostering conservation practices that are socially embedded and ecologically informed.

Taken together, the dynamics of bird utilization, cultural salience, ecological reasoning, and community institutions reveal an integrated socio-ecological system in

which Local Ecological Knowledge operates not merely as a descriptive framework but also as a context-dependent regulatory and ethical reference. Historical subsistence practices, shifting market forces, and the rise of hobby-based bird culture have reconfigured patterns of use, yet these changes continue to be mediated by perceptual, classificatory, and moral logics grounded in aesthetic appreciation, acoustic recognition, and repeated ecological observation. The convergence between folk categories and scientific ecological roles underscores the depth of local interpretive capacity, while variation in hunting intensity, trade preferences, and ethical norms across Java highlights the importance of place-specific socio-cultural contexts. In this sense, Kalibawang exemplifies how LEK-based conservation can emerge organically when cultural identity, ecological knowledge, and informal governance structures operate in mutually reinforcing ways.

Conclusion, this study documents a socially inherited and culturally embedded system of Local Ecological Knowledge (LEK) on birds in Kalibawang based on interviews with 124 respondents across four villages. Bird knowledge is transmitted mainly through patrilineal and male-centered networks, strengthened by mentor–apprentice learning within *lomba kicau* communities. Respondents apply a flexible folk classification that integrates acoustic traits, habitat context, symbolic meaning, and practical relevance, with songbirds as the most salient category. Although 71 species were recorded, most birds (57.7%) are not directly utilized, while extractive use is highly selective and concentrated on cage birds and trade species. Capture is dominated by getah/pulut and netting, whereas cultural taboos contribute to a substantial proportion of non-captured species. LEK generally aligns with scientific knowledge on habitat association and conspicuous behavior, while mismatches mainly reflect symbolic interpretations or context-based inference. This study is limited by its focus on male respondents and a cross-sectional design that captures LEK at a single time point; future work should include gender-comparative approaches, longitudinal tracking of knowledge change, and population-based ecological surveys to assess how market dynamics and cultural practices influence bird populations over time. Integrating LEK with participatory conservation frameworks and agroforestry management offers strong potential to support culturally appropriate, community-based bird conservation in Java.

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Table S1. Bird species recorded in the agroforestry landscapes of Kalibawang, Central Java, Indonesia, with origin and conservation status, as well as habitat, feeding guilds, folk classification, human uses, and method of capture

Family	Scientific name	Local name	Village presence*	Origin	IUCN	Permen LHK 106/2018	CITES	Folk classification	Human use	Method of capture (local context)	Dominant habitat	Feeding guild
Accipitridae	*Elanus caeruleus*	Alap-alap sapi	DP, KS, KL, ML	Native	LC	–	–	Raptor	No direct use	No capture / taboo	Grassland / open fields	Carnivore
Accipitridae	*Nisaetus bartelsi*	Elang Jawa	DP, KS, KL, ML	Native	EN	✓	II	Sacred bird, raptor	Sacred / culturally protected	No capture / taboo	Forest	Carnivore
Aegithinidae	*Aegithina tiphia*	Sirtu / Cipoh	DP, KS, KL, ML	Native	LC	–	–	Songbird	Pet bird / cage bird	Bird glue trapping	Agroforestry	Insectivore
Alaudidae	*Mirafra javanica*	Branjangan	KL, ML	Native	LC	–	–	Rice-field bird	Pet bird / cage bird	Snare trapping	Grassland / open fields	Insectivore
Alcedinidae	*Todiramphus chloris*	Cekakak sungai	DP, KS, KL, ML	Native	LC	–	–	Songbird	No direct use	No capture / taboo	Riverine	Carnivore
Alcedinidae	*Todiramphus cyanoventris*	Cekakak biru	KS	Native	NT	–	–	Songbird	No direct use	No capture / taboo	Riverine	Carnivore
Apodidae	*Collocalia linchi*	Sriti	DP, KS, KL	Native	LC	–	–	None	No direct use	Nest harvesting	Settlements	Insectivore
Apodidae	*Collocalia maxima*	Walet sarang hitam	DP, KS, ML	Native	LC	–	–	None	Edible nest harvested	Nest harvesting	Cliffs / rocky areas	Insectivore
Ardeidae	*Bubulcus ibis*	Kuntul kerbau	DP, KS, KL	Native	LC	–	–	Rice-field bird	Ecosystem service (pest controller)	Projectile hunting	Rice fields	Insectivore
Campephagidae	*Pericrocotus speciosus*	Sepah merah	DP, KS, KL, ML	Native	LC	–	–	Songbird	No direct use	No capture / taboo	Forest	Insectivore
Chloropseidae	*Chloropsis sonnerati*	Cucak ijo	ML	Native	EN	✓	–	Songbird (prestigious)	Pet trade	Bird glue trapping	Agroforestry	Frugivore–Insectivore
Ciconiidae	*Leptoptilos javanicus*	Bangau tongtong	KL	Native	VU	✓	–	Wetland bird	No direct use	No capture / taboo	Wetlands	Scavenger
Cisticolidae	*Cisticola juncidis*	Cici padi	DP, KS, ML	Native	LC	–	–	Rice-field bird	No direct use	Snare trapping	Grassland / open fields	Insectivore
Cisticolidae	*Orthotomus cucullatus*	Cinenen gunung	ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Forest	Insectivore
Cisticolidae	*Orthotomus ruficeps*	Prenjak kepala merah	KS, ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Insectivore
Cisticolidae	*Orthotomus sepium*	Prenjak jawa	KS	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Insectivore
Cisticolidae	*Orthotomus sutorius*	Cinenen pisang	ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Insectivore
Cisticolidae	*Prinia familiaris*	Ciblek jawa	DP, KL	Native	LC	–	–	Songbird	Pet bird / cage bird	Bird glue trapping	Agroforestry	Insectivore

Cisticolidae	*Prinia inornata*	Ciblek sawah	DP, KS, KL, ML	Native	LC	–	–	Rice-field bird	No direct use	Bird glue trapping	Rice fields	Insectivore
Columbidae	*Columba livia*	Merpati batu	KL	Introduced	LC	–	–	Bird of settlement	Domesticated	Netting	Settlements	Granivore
Columbidae	*Columba livia domestica*	Merpati (peliharaan)	DP, KS, ML	Domesticated	NE	–	NE	Poultry	Domesticated	Domesticated breeding	Settlements	Domesticated
Columbidae	*Geopelia striata*	Perkutut	DP, KS, KL, ML	Native	LC	–	–	Songbird (spiritual)	Pet bird / cage bird	Cage trapping	Agroforestry	Granivore
Columbidae	*Spilopelia chinensis*	Derkuku	DP, KS, KL, ML	Native	LC	–	–	Songbird	Pet bird / cage bird	Netting	Rice fields	Granivore
Columbidae	*Streptopelia risoria*	Puter	DP, KS, KL	Domesticated	NE	–	NE	Songbird	Domesticated	Domesticated breeding	Settlements	Domesticated
Corvidae	*Corvus enca*	Gagak hutan	ML	Native	LC	–	–	None	No direct use	Projectile hunting	Forest	Omnivore
Corvidae	*Corvus macrorhynchos*	Gagak besar	KL	Native	LC	–	–	None	No direct use	Projectile hunting	Grassland / open fields	Omnivore
Cuculidae	*Centropus sinensis*	Bubut	ML	Native	LC	✓	–	Pest bird	No direct use	Snare trapping	Agroforestry	Insectivore
Cuculidae	*Surniculus lugubris*	Kedasih	KS, ML	Native	LC	–	–	Sacred bird, omen	No direct use	No capture / taboo	Forest	Insectivore
Dicaeidae	*Dicaeum trigonostigma*	Kemade	ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Frugivore–Nectarivore
Dicaeidae	*Dicaeum trochileum*	Bangsit	DP	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Frugivore–Nectarivore
Dicruridae	*Dicrurus macrocercus*	Srigunting	KS, KL, ML	Native	LC	–	–	Pest bird, predator	No direct use	No capture / taboo	Grassland / open fields	Insectivore
Estrildidae	*Lonchura leucogastroides*	Bondol jawa	DP, KS, KL, ML	Native	LC	–	–	Rice-field bird	No direct use	Netting	Rice fields	Granivore
Estrildidae	*Padda / Lonchura oryzivora*	Gelatik jawa	KS, ML	Native	EN	✓	II	Songbird	Pet trade	Bird glue trapping	Rice fields	Granivore
Fringillidae	*Serinus canaria domestica*	Kenari	DP, KS, ML	Domesticated	NE	–	NE	Cage bird	Domesticated	Domesticated breeding	Settlements	Domesticated
Laniidae	*Lanius schach*	Cendet	DP, KS	Native	LC	–	–	Songbird, predator	Pet bird / cage bird	Bird glue trapping	Agroforestry	Insectivore
Muscicapidae	*Brachypteryx montana crassa*	Sulingan jawa	ML	Native	LC	✓	–	Songbird	No direct use	Netting	Forest	Insectivore
Muscicapidae	*Copsychus malabaricus*	Murai batu	KS, KL, ML	Native	LC	✓	II	Songbird (prestige)	Pet trade	Netting	Forest edge	Insectivore
Muscicapidae	*Copsychus saularis*	Kacer	KS, ML	Native	LC	–	–	Songbird	Pet bird / cage bird	Netting	Agroforestry	Insectivore
Muscicapidae	*Cyanoptila cyanomelana*	Sulingan biru	KS	Native	LC	–	–	Songbird	No direct use	No capture / taboo	Forest	Insectivore
Muscicapidae	*Cyornis banyumas*	Sikatan cacing	DP, ML	Native	NT	✓	–	Songbird	No direct use	Netting	Forest	Insectivore
Muscicapidae	*Monticola solitarius*	Ciung batu	KS	Native	LC	–	–	Songbird	No direct use	No capture / taboo	Cliffs / rocky areas	Insectivore
Muscicapidae	*Myophonus glaucinus*	Ciung-batu	KS	Native	EN	✓	–	Songbird	No direct use	Netting	Riverine	Insectivore

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Nectariniidae	*Aethopyga eximia*	Kolibri	KS, ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore
Nectariniidae	*Aethopyga siparaja*	Sepah raja	KS	Native	LC	✓	–	Songbird	No direct use	Bird glue trapping	Forest edge	Nectarivore
Nectariniidae	*Anthreptes malacensis*	Burung-madu Kelapa	DP	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore
Nectariniidae	*Arachnothera longirostra*	Madu rimba	DP, KS, ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore–Insectivore
Nectariniidae	*Cinnyris asiaticus*	Kolibri ungu	KL	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore
Nectariniidae	*Cinnyris jugularis*	Sriganti	KS	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore
Nectariniidae	*Cinnyris solaris*	Sriganti dada-api	ML	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore
Nectariniidae	*Leptocoma calcostetha*	Sogon	KS	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Nectarivore
Oriolidae	*Oriolus chinensis*	Kepudang kuduk hitam	KL	Native	LC	✓	–	Songbird	No direct use	Netting	Agroforestry	Frugivore–Insectivore
Passeridae	*Passer montanus*	Burung gereja	DP, KS, KL, ML	Native	LC	–	–	Pest bird, settlement bird	No direct use	Netting	Settlements	Granivore
Phasianidae	*Gallus gallus bankiva*	Ayam hutan merah	ML	Native	LC	✓	–	Game bird	Occasionally hunted	Snare trapping	Forest edge	Omnivore
Phasianidae	*Gallus varius*	Ayam hutan hijau	KS, KL	Native	LC	✓	–	Game bird	Occasionally hunted	Snare trapping	Forest	Omnivore
Picidae	*Chrysophlegma flavinucha*	Pelatuk jambul kuning	ML	Native	LC	✓	–	None	No direct use	No capture / taboo	Forest	Insectivore
Picidae	*Dinopium javanense*	Pelatuk bawang	KS	Native	LC	✓	–	None	No direct use	No capture / taboo	Agroforestry	Insectivore
Psittaculidae	*Agapornis* sp.	Lovebird	DP, KS, ML	Domesticated	NE	–	NE	Cage bird	Domesticated	Domesticated breeding	Settlements	Granivore
Psittaculidae	*Loriculus galgulus*	Serindit	ML	Native	LC	✓	II	Songbird	Pet bird / cage bird	Netting	Agroforestry	Frugivore
Psittaculidae	*Psittacula alexandri*	Betet	KL, ML	Native	NT	✓	II	Cage bird	Pet trade	Netting	Agroforestry	Frugivore
Pycnonotidae	*Pycnonotus aurigaster*	Kutilang	DP, KS, KL, ML	Native	LC	–	–	Songbird	Pet bird / cage bird	Bird glue trapping	Agroforestry	Frugivore–Insectivore
Pycnonotidae	*Pycnonotus goiavier*	Trucuk	DP, KS, KL	Native	LC	–	–	Songbird	Pet bird / cage bird	Bird glue trapping	Agroforestry	Frugivore–Insectivore
Pycnonotidae	*Pycnonotus simplex*	Cucak meranti	KS	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Frugivore
Rallidae	*Amaurornis phoenicurus*	Kareo padi	KL	Native	LC	–	–	Wetland bird	No direct use	Snare trapping	Wetlands	Omnivore
Rallidae	*Gallinula chloropus*	Mandar	KL	Native	LC	–	–	Wetland bird	Occasionally hunted	Snare trapping	Wetlands	Omnivore
Rallidae	*Porphyrio indicus*	Mandar besar	DP, KS	Native	LC	–	–	Wetland bird	No direct use	Snare trapping	Wetlands	Herbivore
Strigidae	*Otus angelinae*	Celepuk jawa	DP, KL, ML	Native	NT	✓	–	Predator, sacred bird	Sacred / culturally	No capture / taboo	Forest	Carnivore

Sturnidae	*Acridotheres javanicus*	Jalak kerbau	DP, KS, ML	Native	EN	–	–	Rice-field bird	protected Pet trade	Cage trapping	Grassland / open fields	Omnivore
Sturnidae	*Gracupica contra*	Jalak suren	DP	Native	EN	✓	II	Songbird	Pet trade	Cage trapping	Agroforestry	Omnivore
Timaliidae	*Timalia pileata*	Kaso-kaso	KS	Native	LC	–	–	Songbird	No direct use	Bird glue trapping	Agroforestry	Insectivore
Zosteropidae	*Zosterops flavus*	Pleci dada kuning	KS	Native	EN	✓	–	Songbird	Pet trade	Bird glue trapping	Agroforestry	Nectarivore–Insectivore
Zosteropidae	*Zosterops palpebrosus*	Pleci	DP, KS, KL, ML	Native	LC	–	–	Songbird	Pet bird / cage bird	Bird glue trapping	Agroforestry	Nectarivore–Insectivore

Note:

1. **Village Codes:** DP: Dempel; KS: Karangsambung; KL: Kalialang; ML: Margolangu.
2. **Origin of Species:** Native: Wild, naturally occurring species in Indonesia; Introduced/domesticated: Non-native or captive species found around settlements.
3. **Conservation status:**
    - **IUCN Red List:** LC: Least Concern; NT: Near Threatened; VU: Vulnerable; EN: Endangered.
    - **National status (RI):** Based on Indonesian Regulation Permen LHK No. 106/2018 (protected species list).
    - **CITES:** Appendix I–III (international trade regulation).
4. **Folk (Emic) classification categories:** songbirds (*burung kicau*), rice-field birds (*burung sawah*), wetland or water birds (*burung rawa/air*), sacred or mythical birds (*burung mitos/keramat*), predators (*burung pemangsa*), pest birds (*burung hama tanaman*), aerial raptors (*burung pemangsa udara*), birds of settlements (*burung permukiman*), cage birds (*burung sangkar*), game birds (*burung buruan*), poultry (*unggas*), omen birds (*burung pertanda*), and species that were not classified under any local category (*tidak diklasifikasikan*).
5. **Human use categories:** no direct use, those kept as pet or cage birds, individuals involved in the pet trade, domesticated species, species that are occasionally hunted, birds regarded as sacred or culturally protected, species whose edible nests are harvested, and birds that provide ecosystem services, particularly as natural pest controllers.
6. **Methods of capture:** Bird glue trapping (*getah/pulut*), netting using mist nets or other nets (*jaring*), practices involving no capture due to cultural taboos (*tidak ditangkap / tabu budaya*), snare trapping (*jerat*), domesticated breeding (*domestikasi/ternak*), projectile hunting such as the use of air rifles or slingshots (*penembakan [senapan angin/ketapel]*), cage trapping (*perangkap sangkar/bubu*), and nest harvesting (*pemanenan sarang*).
7. **Habitat types (observed land-use categories):** Agroforestry systems (mixed fruit trees, coffee, bamboo), natural forest (pine forests etc.), forest edges, grasslands or open fields, rice fields (*sawah*), human settlements, wetlands, riverine environments (riverbanks, riparian vegetation), and cliffs or rocky areas/homegardens (*pekarangan*)
8. **Feeding guild classification:** Insectivores, omnivores, granivores, nectarivores, carnivores, frugivore–insectivores, frugivores, nectarivore–insectivores, domesticated species, frugivore–nectarivores, herbivores, and scavengers
9. **Taxonomic reference and synonym notes:**
   Scientific names follow the IOC World Bird List (v.14.2). Some nomenclature differs from Indonesian Permen LHK 106/2018 but refers to the same taxa. Examples:
    - *Padda oryzivora* = *Lonchura oryzivora* (Java Sparrow)
    - *Myophonus glaucinus* = *Myophonus caeruleus* (Javan Whistling Thrush)
    - *Gracupica contra* is sometimes listed as *Sturnus contra*
    - *Dinopium javanense* = *Picus javanensis*
    - *Chrysophlegma flavinucha* = *Picus flavinucha*
10. **Exclusion criteria:** Only wild bird species were included in richness, guild, and conservation analyses. Domesticated poultry (*Gallus domesticus*, *Anas platyrhynchos domesticus*, *Columba livia domestica*) and fully captive ornamental birds were excluded.

Table S2. Alignment between local ecological knowledge and scientific information for selected bird species in Kalibawang, Central Java, Indonesia

Scientific name	Local name	UV	RFC	CI
Elanus caeruleus	Alap-alap sapi	0.01	0.04	0.01
Nisaetus bartelsi	Elang Jawa	0.02	0.05	0.03
Aegithina tiphia	Cipoh	0.01	0.02	0.01
Mirafra javanica	Branjangan	0.01	0.02	0.01
Todiramphus chloris	Cekakak Sungai	0.01	0.07	0.01
Todiramphus cyanoventris	Cekakak Biru	0.01	0.03	0.01
Collocalia linchi	Walet / Sriti	0.01	0.02	0.01
Collocalia maxima	Walet Sarang Hitam	0.01	0.02	0.01
Bubulcus ibis	Kuntul Kerbau	0.01	0.02	0.01
Pericrocotus speciosus	Sepah Merah	0.01	0.03	0.01
Chloropsis sonnerati	Cucak Ijo	0.08	0.09	0.09
Leptoptilos javanicus	Bangau Tongtong	0.01	0.03	0.01
Orthotomus cucullatus	Cinenen Gunung	0.01	0.02	0.01
Orthotomus ruficeps	Prenjak Kepala Merah	0.03	0.09	0.03
Orthotomus sepium	Prenjak Jawa	0.03	0.08	0.03
Orthotomus sutorius	Cinenen pisang	0.01	0.02	0.01
Prinia familiaris	Prenjak Jawa	0.02	0.05	0.02
Prinia inornata	Ciblek Sawah	0.02	0.07	0.02
Columba livia	Merpati Batu	0.01	0.05	0.01
*Columba livia domestica**	Merpati peliharaan	0.01	0.02	0.01
Geopelia striata	Perkutut	0.04	0.12	0.05
Spilopelia chinensis	Derkuku	0.03	0.08	0.04
*Streptopelia risoria**	Puter	0.01	0.02	0.01
Corvus enca	Gagak Hutan Kecil	0.01	0.02	0.01
Corvus macrorhynchos	Gagak Besar	0.01	0.02	0.01
Centropus sinensis	Bubut	0.01	0.02	0.01
Surniculus lugubris	Kedasih	0.01	0.02	0.01
Dicaeum trigonostigma	Kemade	0.01	0.02	0.01
Dicaeum trochileum	Cabai Jawa Merah	0.01	0.02	0.01
Dicrurus macrocercus	Srigunting Hitam	0.01	0.02	0.01
Lonchura leucogastroides	Bondol Jawa	0.04	0.26	0.06
Lonchura oryzivora	Gelatik Jawa	0.07	0.15	0.08
*Serinus canaria domestica**	Kenari	0.01	0.02	0.01
Lanius schach	Cendet	0.01	0.02	0.01
Cisticola$ juncidis	Cici Padi	0.02	0.10	0.03
Brachypteryx montana crassa	Sulingan Jawa	0.01	0.02	0.01
Copsychus malabaricus	Murai Batu	0.12	0.36	0.15
Copsychus saularis	Kacer	0.10	0.31	0.12
Cyanoptila cyanomelana	Sulingan Biru	0.01	0.03	0.01
Cyornis banyumas	Sikatan Cacing	0.01	0.02	0.01
Monticola solitarius	Ciung Batu	0.01	0.03	0.01
Myophonus glaucinus	Ciung Biru	0.01	0.03	0.01
Aethopyga eximia	Kolibri Jawa	0.02	0.09	0.02
Aethopyga siparaja	Sepah Raja	0.01	0.06	0.01
Anthreptes malacensis	Burung-madu Kelapa	0.02	0.06	0.02
Arachnothera longirostra	Sogon Rimba	0.01	0.02	0.01
Cinnyris asiaticus	Kolibri Ungu	0.01	0.02	0.01
Cinnyris jugularis	Sriganti	0.02	0.11	0.02
Cinnyris solaris	Sriganti dada-api	0.02	0.07	0.02
Leptocoma calcostetha	Sogon	0.01	0.02	0.01
Oriolus chinensis	Kepodang	0.03	0.10	0.03
Passer montanus	Burung Gereja	0.03	0.20	0.05
Gallus gallus bankiva	Ayam Hutan Merah	0.08	0.10	0.09
Gallus varius	Ayam Hutan Hijau	0.05	0.08	0.06
Chrysophlegma flavinucha	Pelatuk Jambul Kuning	0.01	0.02	0.01
Dinopium javanense	Pelatuk Bawang	0.01	0.02	0.01
Agapornis sp.*	Lovebird	0.01	0.02	0.01
Loriculus galgulus	Serindit	0.06	0.07	0.07
Psittacula alexandri	Betet Jawa	0.04	0.06	0.05
Pycnonotus aurigaster	Kutilang	0.05	0.22	0.06
Pycnonotus goiavier	Trucuk	0.04	0.23	0.05
Pycnonotus simplex	Cucak Meranti	0.01	0.05	0.01
Amaurornis phoenicurus	Kareo Padi	0.02	0.07	0.02
Gallinula chloropus	Mandar	0.01	0.05	0.01
Porphyrio indicus	Bluwok	0.01	0.03	0.01
Otus angelinae	Celepuk Jawa	0.01	0.02	0.01
Acridotheres javanicus	Jalak Kerbau	0.06	0.18	0.06
Gracupica contra	Jalak Suren	0.05	0.14	0.06
Timalia pileata	Kaso-kaso	0.01	0.02	0.01
Zosterops flavus	Pleci Dada Kuning	0.01	0.04	0.01
Zosterops palpebrosus	Pleci	0.03	0.12	0.03

Note. *: Domestic. UV: Use Value; RFC: Relative Frequency of Citation; CI: Cultural Importance Index. Values are derived from interview data (N = 124) and field observations. Species with very low mentions were assigned baseline values (UV = 0.01; RFC = 0.02; CI = 0.01). Four domesticated species (*Columba livia domestica*, *Streptopelia risoria*, *Serinus canaria domestica*, *Agapornis* sp.) are listed due to cultural relevance but are not part of the wild avifauna and thus considered Not Evaluated (NE) for conservation analysis

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Ruderal flora as ethnoecological capital for urban conservation policy in Kupang City, Indonesia

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Abstract. *Gaol ML, Dewi IAL, Mudita IW. 2025. Ruderal flora as ethnoecological capital for urban conservation policy in Kupang City, Indonesia. Asian J Ethnobiol 8: 390-401.* Accelerating urbanization in tropical cities like Kupang, Indonesia, disrupts green spaces and reshapes spontaneous herbaceous plant communities, which are vital for urban biodiversity. To assess these impacts, field surveys compared flora across urban and peri-urban gradients, revealing 91 species with significantly higher richness and diversity in peri-urban areas. Invasive species dominated the urban core flora, indicating biotic homogenization, while sensitive flora were found mainly in the peri-urban. Crucially, this herbaceous vegetation holds immense socio-ecological value, with 94.51% of species having medicinal uses, and peri-urban corridors supporting multifunctional species that provide material and environmental services. Policy analysis, nevertheless, indicated that current urban planning overlooked these ruderal corridors and lacks specific diversity metrics. This study establishes that peri-urban ruderal flora constitutes a significant form of ethnoecological capital, highlighting its critical importance as a reservoir of both biodiversity and ethnobotanical knowledge. By linking ecological gradients with policy analysis, this study emphasizes the urgency of safeguarding spontaneous vegetation within rapidly transforming urban landscapes. The findings provide a scientific basis for re-evaluating urban conservation strategies to incorporate these socio-ecological values into resilience planning for tropical secondary cities.

Keywords: Biotic homogenization, herbaceous species diversity, policy integration, ruderal corridors, urban-rural gradient

INTRODUCTION

Urbanization is a dominant driver of global environmental change, reconfiguring ecological communities through habitat alteration, fragmentation, and the introduction of synergistic stressors such as impervious surfaces and urban heat islands (Grimm et al. 2008; Seto et al. 2012). These anthropogenic filters act as selective agents, determining species colonization, extirpation, and the distribution of functional traits, leading to distinct urban species pools (Johnson et al. 2013; Aronson et al. 2016). The urban-rural gradient paradigm provides a foundational framework for quantifying these effects, revealing systematic shifts in biodiversity from rural peripheries to urban cores (McDonnell and Hahs 2008). This gradient encapsulates changes in human population density, land-use intensity, and impervious surface cover, allowing researchers to unravel urbanization's impact on ecological processes and biodiversity metrics, such as native species loss and biotic homogenization the increasing dominance of widespread, disturbance-tolerant species (Nagy and Lockaby 2011; Pickett et al. 2011).

The spatial heterogeneity of cities underpins characteristic vegetation patterns along these anthropogenic gradients. Urban ecological research frequently applies zonation models to demonstrate that strong contrasts in floristic composition and community structure between zones (e.g., urban core, suburban, peri-urban) are due to interacting biophysical and socio-economic drivers (Kowarik 1991; Pickett et al. 2011; Aronson et al. 2016). Such research shows that land-use types such as central business districts, residential areas, and transportation corridors contain characteristic plant assemblages directly related to their disturbance regimes and habitat connectivity (McDonnell and Hahs 2008; Rega-Brodsky et al. 2022). This kind of research is pivotal for urban biodiversity conservation, invasive species management, and the use of vegetation for climate adaptation (Elmqvist et al. 2013). Furthermore, urban flora delivers fundamental ecosystem services, from mitigating air pollution to providing cultural benefits, offering important insights for evidence-based green infrastructure design (Haase et al. 2014; Norton et al. 2015).

In tropical regions, secondary cities are experiencing rapid urban expansion, yet their unique biodiversity dynamics remain critically understudied compared to larger metropolises (Seto et al. 2011; McDonald et al. 2020). Indonesia, a tropical biodiversity hotspot, exemplifies this trend, where urban growth often outpaces the implementation of ecological safeguards in spatial

planning. Within these cities, spontaneous herbaceous communities are a vital yet underappreciated component of urban biodiversity, providing essential ecosystem services but disproportionately impacted by habitat degradation (Tredici 2010; Ilie and Cosmulescu 2023). Crucially, this spontaneous vegetation often constitutes a significant form of ethnoecological capital, providing accessible medicinal, nutritional, and material resources for urban communities (Arifin and Nakagoshi 2011; Ayuningrum et al. 2024), making it a key subject for ethnobiological research that links ecological patterns directly to human wellbeing (Shackleton et al. 2017; Yuliana et al. 2025). However, within the Indonesian context, urban ecological studies have predominantly focused on floristic inventories, with a limited ethnobotanical focus on the socio-ecological value of spontaneous vegetation (Arifin and Nakagoshi 2011; Latifah et al. 2021; Hakim et al. 2024).

Urban ethnobotanical studies are crucial for exploring the dynamic relationships between urban residents and plants, providing a foundation for integrating local knowledge into urban planning. Such integration can guide the selection of plant species that offer dual ecological and socio-cultural benefits, thereby enhancing environmental quality and conserving local biodiversity amidst urban expansion. In Indonesia, a growing body of research has documented urban ethnobotanical knowledge, focusing on the potential of bamboo in city forests (Adhinata et al. 2023) and the prevalence of medicinal plants in various urban settings (Rizal et al. 2021; Nikmatullah et al. 2022; Aini et al. 2024; Safitri et al. 2024; Putri et al. 2025). However, as noted by Sujarwo (2023), the dominant focus of these studies remains on medicinal plant use and diversity inventories. Consequently, urban ethnobotanical research that explicitly links plant use to biodiversity conservation and ecological maintenance strategies remains relatively underdeveloped.

This study focuses on Kupang City, the capital of East Nusa Tenggara Province, Indonesia—an urbanizing tropical hub experiencing significant in-migration and land conversion (Seto et al. 2011; BPS Kota Kupang 2024). As with other rapidly developing tropical secondary cities, the integration of fine-scale floristic gradient analysis with ethnoecological valuation and policy gap analysis remains relatively unexplored and receives less attention. Therefore, this study aims to examine the effects of urbanization on Kupang's herbaceous communities by: (i) assessing how species richness, diversity, and composition vary along an urban-peri-urban gradient; (ii) evaluating the anthropogenic use potential (ethnoecological value) of the prevailing flora; and (iii) analyzing how existing local and national policies align with the conservation of these communities. By synthesizing ecological, ethnobotanical, and policy data, this research will provide actionable insights into the need to integrate ruderal flora and its associated socio-ecological value into urban resilience planning.

MATERIALS AND METHODS

Study area

This study was conducted in Kupang City (10°36'14"S-10°39'58"S; 123°32'23"E-123°37'01"E), the largest urban hub on Timor Island, Indonesia, located along the northwestern shore of Kupang Bay (Figure 1) (BPS Kota Kupang 2024). Having a tropical savanna climate (Köppen Aw) characterized by a pronounced dry season from April to November, with an average annual rainfall of 1,443 mm and a mean temperature of 27.6°C, the city covers 180.27 km² of mostly anthropogenic landscapes, whose land use consists of residential areas (56.2%), industrial zones (4.1%), green belts (28.2%), and scattered lots for commercial, infrastructure, and institutional purposes (Verburg et al. 2004; BPS Kota Kupang 2024). This tropical climate regime features 7-8 arid months per year, driven by continental air masses from Australia, presenting a significant constraint on urban vegetation dynamics (Byrne 2022).

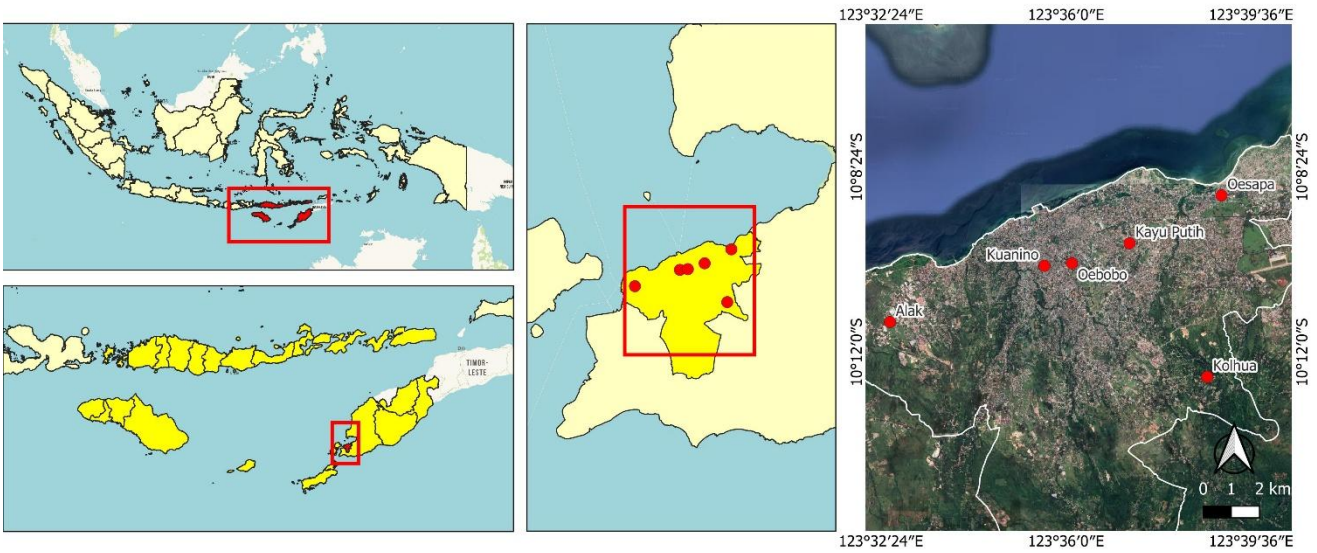

Figure 1. Study area map of Kupang City, East Nusa Tenggara, Indonesia, showing sampled urban core (Kuanino, Oebobo, Kayu Putih) and peri-urban (Kolhua, Alak, Oesapa) sites

Procedures

This study integrated field surveys with analysis of policy documents. Fieldwork employed stratified sampling along an urban gradient in Kupang City. Prior to field activities, a comprehensive review of national and regional policies, including central, provincial, and city laws and regulations (e.g., UU No. 32/2024, PP No. 21/2021, PERDA NTT No. 1/2011, PERDA Kota Kupang No. 12/2011) was conducted, along with research on Indonesian urban herbaceous dynamics (Hakim et al. 2024; Kiswantoro et al. 2024).

Based on urbanization intensity, three peri-urban (Oesapa, Alak, Kolhua) and three urban core (Kuanino, Oebobo, Kayu Putih) sites were selected for the study. Within each site, 20 randomized 1 m² quadrats (total n=120) were established. All herbaceous species were recorded, with density and percentage cover documented using the Braun-Blanquet scale. Species were classified as invasive/non-invasive using standardized criteria from the Guidebook of Invasive Alien Plant Species in Indonesia (Suryawati et al. 2015), cross-referenced with global databases (Weber 2003; GBIF 2023).

Voucher specimens were collected following ethical scientific collection guidelines, deposited at the Biology Laboratory of Universitas Nusa Cendana, Kupang (voucher series KPH-2024-001-120), and identified using regional floras (Soerjani et al. 1987; Tjitrosoedirdjo et al. 2016) and online platforms (Plants of the World Online (POWO) https://powo.science.kew.org/; World Flora Online (WFO) https://www.worldfloraonline.org/; iNaturalist https://www.inaturalist.org/). Given the limitation of not conducting primary ethnobotanical research, ethnoecological uses were determined through a literature synthesis of regional ethnobotanical studies (Martin 1995; Mangalik and Susandarini 2025) and databases (PROSEA https://prosea.prota4u.org/, GBIF https://www.gbif.org/). This approach was taken to establish a foundational understanding of potential use values, acknowledging that the documented uses are compiled from the broader regional literature rather than from primary data from local informants in Kupang City. The implications of this methodological choice are considered in the Discussion.

Data analysis

Standard phytosociological parameters (density, frequency, dominance, and Importance Value Index) were computed according to Mueller-Dombois and Ellenberg (2003). Species diversity was measured using the Shannon-Wiener Index (H'), with diversity class interpretations (low, moderate, high). Floristic similarity was assessed using Sørensen's coefficient. Species were categorized by urban tolerance following modified definitions from Wittig et al. (1985).

Calculation of phytosociological parameters

All phytosociological parameters were calculated according to standardized ecological methods (Mueller-Dombois and Ellenberg 2003). Density (DE) was calculated as the number of individuals per unit area, with Relative Density (RDE) expressed as RDE = (Species density/Total density) × 100. Dominance (DO) was determined as basal cover percentage per species, with Relative Dominance (RDO) calculated as RDO = (Species cover/Total cover) × 100. Frequency (FE) represented the percentage of quadrats containing the species, with Relative Frequency (RFE) expressed as RFE = (Species frequency/Total frequency) × 100. The Importance Value Index (IVI) was derived as the sum of these relative values: IVI = RDE + RDO + RFE.

Diversity and similarity indices

Species diversity was measured with the Shannon-Wiener Index (H'):

$H' = -\Sigma[(ni/N) \times \log(ni/N)]$

Where, ni represents the importance value of species i, and N denotes the total importance value of all species (Magurran 2004). Resulting diversity values were interpreted as: low ($H' \leq 1$), moderate ($1 < H' < 3$), or high ($H' \geq 3$). Floristic similarity between urban and peri-urban areas was assessed using Sørensen's coefficient (Ss): $Ss = 2a/(2a + b + c)$, where a indicates the number of species common to both areas, b represents species unique to the first area, and c denotes species unique to the second area (Mueller-Dombois and Ellenberg 2003).

Urban tolerance classification

Species were categorized according to their distribution along the urbanization gradient using a modified classification system (Wittig et al. 1985; Knapp et al. 2010): (i) Urbanophobic: Restricted to peri-urban areas. (ii) Moderately urbanophobic: Present in both areas, but dominant in peri-urban zones. (iii) Urban-neutral: No distribution preference. (iv) Moderately urbanophilic: Present in both areas, but dominant in urban cores. (v) Urbanophilic: Restricted to urban core areas. All statistical analyses were performed using R version 4.3.1 (R Core Team 2023) with the vegan package for diversity calculations.

Thematic analysis of policy documents and peer-reviewed journal articles on the dynamics of urban herbaceous species was conducted using NVivo 14 (Luminero 2023). Initial codes were derived deductively from key concepts in the literature (e.g., "biodiversity conservation," "native species use," "ecological function"). These codes were iteratively grouped into overarching themes through comparative analysis, following the framework of Braun and Clarke (2022). The utilities of species were categorized through literature synthesis into functional categories: medicinal, food, fodder, ornamental, material resources, and environmental enhancement (Martin 1995; Mangalik and Susandarini 2025).

RESULTS AND DISCUSSION

Structure, composition, and distribution of herbaceous species

Floristic surveys along the urban gradient revealed significant ecological differentiation between zones (Figures 2 and 3). Peri-urban areas supported substantially

greater species richness (62 species vs. 43 in the urban core) and consequently lower maximum Importance Value Indices (IVI) (8.40% vs. 14.95%). Shannon diversity was also higher in peri-urban areas (H′ = 2.60) compared to urban cores (H′=2.28). Compositional analysis demonstrated distinct dominant species between zones, with peri-urban communities characterized by *Synedrella nodiflora* and *Digitaria sanguinalis*. At the same time, urban cores were dominated by invasive ruderals *Paspalum conjugatum* and *Stenotaphrum secundatum* (Table 1). The Importance Value Index (IVI) stratification revealed a strong hierarchical organization, with 68.13% of species in the lowest IVI class (<1) (Table 2), conforming to Preston's law of species abundance. Urban tolerance spectra showed that 52.75% of the species were urbanophobic, concentrated mainly in peri-urban areas (Table 3, Figure 3.C). Floristic similarity between the zones was low, with a Sørensen's coefficient of 21.05%.

Table 1. Dominant herbaceous species by urban zone in Kupang City, East Nusa Tenggara, Indonesia, based on mean Importance Value Index (IVI)

Zone	Species	Mean IVI (±SE)	Functional role
Peri-urban	*Synedrella nodiflora* (Asteraceae)	8.7±0.4	Native pioneer
	Digitaria sanguinalis (Poaceae)	7.2±0.3	C_4 grass competitor
Urban Core	*Paspalum conjugatum* (Poaceae)	14.2±0.8	Invasive ruderal
	Stenotaphrum secundatum (Poaceae)	11.5±0.6	Mat-forming alien

Table 2. Distribution of herbaceous species in Kupang City, East Nusa Tenggara, Indonesia, by Importance Value Index (IVI) category

IVI category	% Species	% Total IVI	Ecological significance
Very High (>4)	5.49	27.52	Ecosystem engineers
High (3-4)	3.3	10.57	Competitive dominants
Medium (2-3)	4.4	10.32	Subordinate stabilizers
Low (1-2)	18.68	22.73	Stress-tolerant specialists
Very Low (<1)	68.13	28.87	Rare/transient specialists

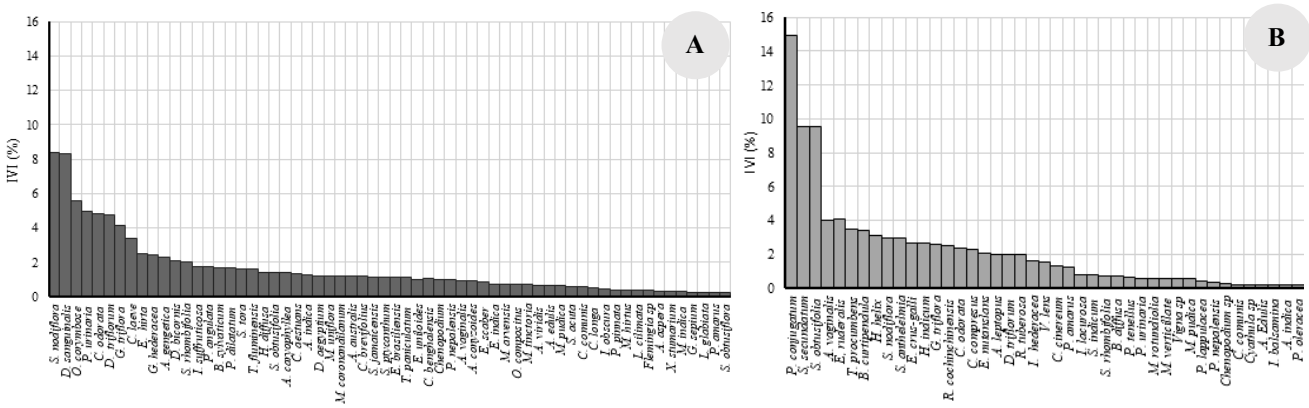

Figure 2. Floristic differentiation of herbaceous species along peri-urban-urban core gradient. A. Peri-urban and B. Urban core

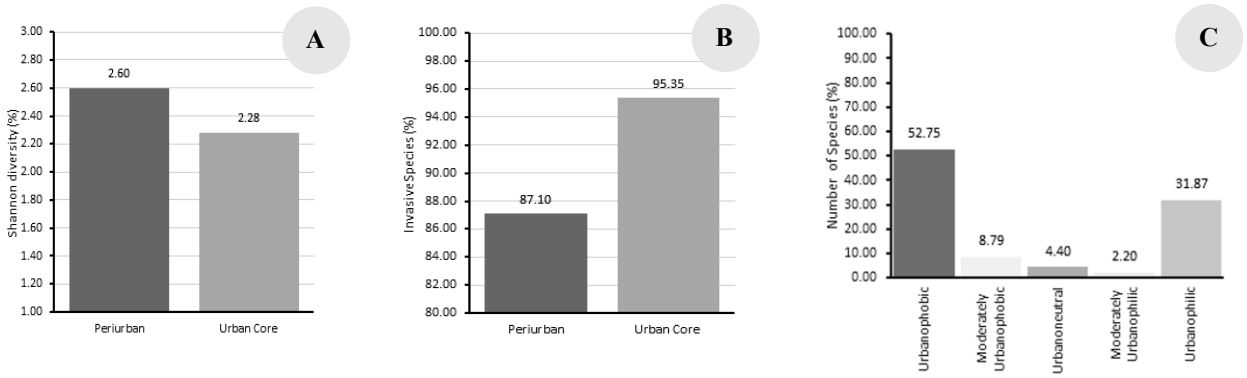

Figure 3. Hierarchical organization of herbaceous species across peri-urban-urban core gradient. A. Species diversity, B. Invasive species, and C. Species tolerance spectra

The pronounced differentiation in species composition along the peri-urban-urban core gradient demonstrates substantial biotic homogenization driven by urbanization. This pattern aligns with global studies showing urban environments filter out disturbance-sensitive specialists while favoring cosmopolitan ruderal species (Table 4) (McKinney 2006; Johnson et al. 2013). The concentration of urbanophobic species in peri-urban areas indicates these zones serve as critical refugia and a critical priority for conservation. These findings underscore the conservation value of urban peripheries in tropical secondary cities, where rapid urbanization often outpaces the development of green infrastructure. Peri-urban areas thus function as crucial reservoirs for native biodiversity, maintaining ecological functions that are lost in increasingly homogenized urban cores.

Families of herbaceous plant species

Family-level analysis revealed pronounced ecological filtering along the urbanization gradient. Poaceae and Fabaceae collectively constituted 57.02% of urban core IVI compared to 36.44% in peri-urban areas, indicating increased (↑) functional homogenization under urban pressure (Table 5). The Poaceae family showed powerful ruderal dominance in urban cores (IVI 35.36% vs. peri-urban 20.04%), while Fabaceae exhibited niche expansion in peri-urban areas (11 species vs. urban core 7). Despite 14 families being common to both zones, urban cores exhibited reduced phylogenetic diversity within dominant families, particularly a 36% reduction in Fabaceae species richness compared to peri-urban areas.

The dominance of these two families reflects not only their evolutionary adaptations to disturbed environments but also their significant, yet distinct, ethnoecological roles. The prevalence of Poaceae, with traits like rhizomatous growth and C_4 photosynthesis, aligns with their high utility as material resources, providing fodder and raw materials in heavily managed urban cores (Table 6). Conversely, the Fabaceae's success, facilitated by nitrogen-fixing symbioses, is paralleled by their high value as sources of nutrition and traditional medicine, a function particularly vital in peri-urban areas where these species are more diverse. This phylogenetic truncation in urban cores, where stress-tolerant clades outcompete complex lineages, mirrors global patterns of urban floral homogenization (He et al. 2024). The findings suggest that urban planning should prioritize native species from these families not only to enhance ecosystem resilience but also to conserve their distinct ethnoecological capital—leveraging Poaceae for material services and Fabaceae for nutritional and medicinal resources—while simultaneously conserving vulnerable families like Phyllanthaceae and Euphorbiaceae that show greater sensitivity to urbanization pressures and often possess unique ethnobotanical applications.

Table 3. Urban tolerance categories of herbaceous species documented in Kupang City, East Nusa Tenggara, Indonesia

Category	% Species	Representative taxa	Primary habitat	Conservation priority
Urbanophobic	52.75	*Grona triflora* and *G. heterophylla* (Fabaceae)	Peri-urban	Critical
Moderately urbanophobic	8.70	*Phyllanthus urinaria* (Phyllanthaceae)	Transitional	High
Urbanophilic	31.87	*Alysicarpus vaginalis* (Fabaceae)	Urban core	Low
Moderately urbanophilic	2.20	*Phyllanthus amarus* Phyllanthaceae)	Transitional	Low
Urbanoneutral	4.40	*Mimosa pudica* (Fabaceae)	Ubiquitous	Moderate

Table 4. Comparison of urban tolerance patterns in herbaceous species from Kupang City, East Nusa Tenggara, Indonesia, with global studies

Region/Study	Urbanophobic %	Urbanophilic %	Key refugia	Richness driver
Kupang, Indonesia (this study)	52.75	31.87	Peri-urban grasslands	Microhabitat preservation
Rural Poland (Galera et al. 2012)	7-31	<3	Pond margins	Hydrological features
Central European railways (Dziuba et al. 2022)	Dominant	Low	Ballast corridors	Disturbance intermediacy
Henan Province, China (Zhang et al. 2024)	–	–	Suburban greenbelts	Regional species pool

Table 5. Importance Value Index (IVI) and species richness of dominant plant families along the urban gradient in Kupang City, East Nusa Tenggara, Indonesia

Family	Urban core IVI (%)	Peri-urban IVI (%)	ΔIVI	Urban core spp.	Peri-urban spp.	Conservation priority
Poaceae	35.36	20.04	+15.32↑	6	10	Invasive control
Fabaceae	21.66	16.40	+5.26↑	7	11	Native promotion
Asteraceae	14.78	15.28	-0.50↓	5	5	Neutral
Phyllanthaceae	3.92	8.15	-4.23↓	2	3	Peri-urban refugia
Euphorbiaceae	2.87	6.33	-3.46↓	3	4	Ethnoecological focus
Total Top 2	57.02	36.44	+20.58	13	21	

Beyond their role in enhancing urban ecosystem resilience, the Fabaceae and Poaceae families hold significant ethnobotanical value as primary sources of food, medicine, and material resources. Globally, these are among the most economically and culturally important plant families (Wariss et al. 2016). The Fabaceae family is crucial for its use as food crops, green manure, and animal feed. Furthermore, species within this family are sources of a wide array of natural products, including flavors, dyes, poisons, and medicines (Patel and Shah 2014). Their socioeconomic importance extends to the provision of resources such as wood, resins, insecticides, and fibers (Isely 1982). Similarly, the Poaceae family is indispensable to humanity, serving as a primary food source, building material, medicine, fodder, fuel, and fulfilling cultural purposes (Kumari and Saggoo 2015). Specific grass species are used as dietary supplements, food flavorings, animal feed, and treatments for human ailments. Particular species also feature in cultural practices, such as being used as incense in religious ceremonies, insecticides, and for producing natural dyes (Kumari and Saggoo 2015).

Potential value of herbaceous species

The literature-documented ethnoecological uses of the recorded herbaceous species in Kupang are substantial, with 94.51% of species documented for medicinal uses and 16.48% as material sources (Table 7). Peri-urban areas showed particular preeminence in medicinal uses (96.77%), while urban cores had higher proportions of fodder resources (25.58%). Multifunctional high-value species included *Urtica dioica* (material/medicinal) and *D. sanguinalis* (material/phytoremediation) (Table 8), though their service bundles remain excluded from formal planning frameworks.

The exceptionally high medicinal prevalence indicated by the literature suggests that spontaneous urban vegetation constitutes a significant, though not yet locally verified, potential community health resource. Based on regional ethnobotanical records, these species likely represent a vital pharmacopeia, particularly for urban populations in low-income communities where access to formal healthcare may be limited (Safitri et al. 2024). Traditional knowledge associated with these plants represents significant ethnobotanical capital that enhances community resilience to health and economic stresses. However, this study's reliance on literature synthesis means these uses represent potential, rather than actively practiced, value in Kupang. This critical distinction underscores the imperative for future primary ethnobotanical research to validate which of these documented uses are actively maintained by local communities and to quantify the actual reliance on this flora for health and livelihood. The concentration of medicinal species in peri-urban areas underscores the importance of conserving these zones not merely as ecological buffers but as potential repositories of biocultural heritage that could inform community-based health initiatives.

Table 6. Functional traits and ecosystem services of the two most dominant plant families in global urban flora

Family	Key adaptive traits	Urban ecosystem service	Global species	Kupang IVI (%)	Conservation priority
Poaceae	Rhizomatous growth C_4 photosynthesis Fire/grazing tolerance	Erosion control UHI mitigation	12,000 (Christenhusz and Byng 2016)	32.05	Slope stabilization
Fabaceae	Nitrogen fixation Drought tolerance Deep rooting	Soil remediation Pollinator support	19,000 (LPWG 2023)	14.18	Degraded land rehab

Table 7. Ethnoecological uses of documented herbaceous species in urban core and peri-urban areas of Kupang City, East Nusa Tenggara, Indonesia

Use category	Urban core (n=43 spp.) (%)	Peri-urban (n=62 spp.) (%)	Overall (n=91 spp.) (%)	Policy priority
Medicinal	93.02	96.77	94.51	Critical
Material sources	18.64	12.90	16.48	High
Environmental uses	37.21	29.03	31.87	High
Food ingredients	27.91	25.81	28.57	Moderate
Fodder	25.58	14.52	17.58	Context-dependent

Table 8. High-priority multifunctional herbaceous species for conservation in Kupang City, East Nusa Tenggara, Indonesia

Species	Medicinal	Material Source	Environmental	Food/fodder	Conservation action
Urtica dioica	Yes	Textile fiber	-	-	Green industry zones
Digitaria sanguinalis	Yes	Paper fiber	Phytoremediation	Grain/flour	Brownfield remediation
Lantana camara	Yes	Handmade paper (62% cellulose)	Erosion control	-	Invasive-to-resource conversion
Vigna sp.	Yes	-	Biodiversity conservation	Edible beans	Agroecological corridors

Policy analysis and synthesis

Indonesia's regulatory framework establishes a robust legal foundation for biodiversity-sensitive urban planning, with national laws embedding conservation as a core principle and ministerial regulations requiring native vegetation in green open spaces (*Ruang Terbuka Hijau*, RTH). Kupang's local regulations further emphasize the conservation of local flora, explicitly linking the use of native species to "local ecological identity" (Table S1).

Despite this robust framework, a significant implementation gap persists, particularly concerning the conservation of spontaneous flora and its associated ethnoecological capital. Current policies overlook the specific conservation needs of ruderal corridors and the vast majority (94.51%) of documented species with medicinal value, which form a critical, informal health infrastructure for urban communities. Kupang's key local regulation predates national biodiversity amendments and lacks explicit diversity metrics or mechanisms for conserving spontaneous vegetation. This policy gap directly contradicts the empirical evidence from this study, which identifies peri-urban ruderal corridors as vital refugia for urbanophobic species and reservoirs of multifunctional flora. Current research demonstrates that these very corridors significantly enhance urban resilience through climate adaptation and socio-ecological co-benefits (Table S2), yet they remain absent from formal spatial plans. The primary barriers include competing urban land demands, limited budgetary allocation for non-ornamental greenery, and the absence of community engagement mechanisms for co-managing these ethnobotanically rich flora (Kiswantoro et al. 2024). Overcoming these challenges requires transitioning from vague mandates to specific actions: formalizing protection of ruderal corridors, creating municipal native plant nurseries, and establishing community stewardship programs for vacant lots.

Discussion

Results from Kupang City represent a prevailing trend of ecological filtering by urbanization toward biotic homogenization; remarkably, peri-urban areas show significantly higher species richness, diversity, and ethnoecological value than the urban core. The observed gradient is consistent with worldwide urbanization, in which an increase in impervious cover and anthropogenic disturbances favors the establishment of stress-tolerant alien species while reducing specialist indigenous taxa (Aronson et al. 2014; McDonald et al. 2020). The dominance of Poaceae and Fabaceae in the urban core reflects a broad response to disturbance and is likely an evolutionary predisposition for their successful establishment (He et al. 2024). Nonetheless, the context for Kupang City as a tropical secondary city reveals distinctive characteristics, particularly the extraordinary ethnoecological value of spontaneous vegetation, with 94.51% of species possessing medicinal uses that likely serve as essential healthcare resources for urban communities.

The conservation implications transcend mere preservation of biodiversity to include community health, climate resilience, and cultural preservation. The high prevalence of medicinal plants suggests that spontaneous vegetation constitutes critical informal infrastructure for public health, particularly for economically vulnerable populations in the urban core (Shackleton et al. 2017). Simultaneously, ruderal corridors and peri-urban refugia deliver low-cost climate adaptation benefits, such as urban temperature mitigation and stormwater management – benefits of immense value in secondary cities with constrained resources (Elmqvist et al. 2019). A key limitation of this study, however, is that the ethnobotanical data are derived from the literature rather than from primary fieldwork. This means the reported uses indicate significant potential ethnoecological capital, but do not confirm the extent of active local knowledge or application within Kupang's communities. This distinction is critical to avoid overclaiming and underscores the need for future in-depth ethnobotanical surveys to ground-truth these findings. The overriding challenge lies in reconciling formal planning paradigms with the informal ecological and cultural values embodied in spontaneous urban nature.

These findings compellingly make the case for reconceptualizing urban conservation policy in tropical secondary cities. Rather than imposing conventional ornamental landscaping, our evidence indicates that planning could recognize and harness the existing ethnoecological capital of spontaneous flora. The data from this study provide a scientific rationale for several strategic interventions: integrating ruderal corridors into spatial plans to protect documented refugia for urbanophobic species, prioritizing native species with high ecosystem service values in municipal planting programs, and developing frameworks that legitimize community-based management of spontaneous vegetation. Such changes will have implications that require addressing real-world barriers, including political resistance to "unmanaged" vegetation, budgetary reallocation from ornamental to functional landscaping, and the development of participatory frameworks for community engagement. The potential benefit of this approach is that Kupang City and similar cities could develop locally adapted, culturally relevant urban landscapes that enhance both biodiversity and human wellbeing, as demonstrated by the ecological and ethnoecological patterns revealed in this study.

Overall, this work demonstrates that urbanization in Kupang City catalyzes significant biotic homogenization, progressively filtering herbaceous communities toward stress-tolerant invasive species in urban cores while peri-urban areas maintain higher diversity and function as crucial refugia for specialist species. The findings reveal three fundamental patterns: a clear floristic divergence with reduced richness (43 vs. 62 species) and diversity (H' = 2.28 vs. 2.60) in urban cores; the exceptional potential ethnoecological value of spontaneous vegetation, with 94.51% of species possessing documented medicinal uses; and a pronounced policy-implementation gap where existing regulatory frameworks for biodiversity conservation lack specific mechanisms for protecting

ruderal corridors and spontaneous vegetation. Collectively, the findings establish that peri-urban areas in tropical secondary cities constitute essential reservoirs of both biodiversity and documented ethnobotanical knowledge, whose conservation is imperative for maintaining urban ecological resilience and community wellbeing amid accelerating urbanization.

To address the emerging challenges, the evidence from this study points to several targeted policy and management implications. First, the documented value of peri-urban ruderal corridors provides a strong justification for their formal incorporation into Kupang's spatial plans to enhance ecological connectivity and protect urbanophobic species. Second, the prevalence of multifunctional species, particularly within the Fabaceae family, supports a strategic shift in municipal planting programs toward native species that deliver both ecological services (e.g., nitrogen fixation) and ethnoecological benefits. Third, the concentration of medicinal species in spontaneous vegetation creates a compelling rationale for developing community co-management models that can bridge the gap between formal policy and informal ethnobotanical practice. Implementation of these approaches would need to address identified barriers through budget reallocation, participatory planning, and capacity-building programs focused on the value of spontaneous urban flora.

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Table S1. Indonesian policy framework relevant to urban biodiversity conservation

Regulation	Article/ paragraph	Relevant quote (Original Bahasa Indonesia)	English translation
UU No. 32/2024 (Biodiversity Conservation)	Art. 5 Par. (1)	"Konservasi sumber daya alam hayati ... dilakukan melalui kegiatan ... pemanfaatan secara lestari"	"Conservation of biological resources ... is conducted through ... sustainable utilization activities."
PP No. 21/2021 (National Spatial Planning)	Art. 12 Par. (1)	"Penataan ruang wilayah ... harus memperhatikan ... pelestarian keanekaragaman hayati"	"Spatial planning ... must consider ... the preservation of biodiversity."
PP No. 22/2021 (Environmental Protection and Management)	Art 6 letter d	"Perlindungan ... keanekaragaman hayati ... untuk mempertahankan fungsi lingkungan hidup"	"Protection ... of biodiversity ... to maintain environmental functions."
	Art. 8 Par. (1)	"Pemanfaatan sumber daya alam ... harus menjamin kelestarian fungsi ekologis"	"Utilization of natural resources ... must guarantee the sustainability of ecological functions."
Permen ATR/BPN No. 14/2022 (Green Open Space Provision)	Art. 3 Par. (2)	"Vegetasi pada RTH ... menggunakan jenis tanaman asli (lokal) yang beraneka ragam dan memiliki nilai ekologis tinggi"	"Vegetation in Green Open Spaces ... uses diverse native (local) plant species with high ecological value."
Permen PUPR No. 5/2008 (Urban Green Space Guidelines)	Art. 4 Par. (3)	"Pemilihan jenis tanaman ... mengutamakan tanaman asli daerah ... yang memiliki nilai ekologis"	"Plant species selection ... prioritizes native regional plants ... with ecological value."
Perda NTT No. 1/2011 (Spatial Planning of ENT Province)	Art. 17 Par. (1)	"RTRW Provinsi ... mengarahkan perlindungan kawasan bernilai keanekaragaman hayati tinggi"	"The Provincial Spatial Plan ... directs the protection of areas with high biodiversity value."
Perda Kota Kupang No. 12/2011 (Spatial Planning of Kupang City)	Art. 8 Par. (4)	"Ruang Terbuka Hijau ... berfungsi ... sebagai habitat flora lokal dan penjaga keseimbangan ekosistem perkotaan"	"Green Open Spaces ... function ... as habitats for local flora and maintainers of urban ecosystem balance."
Perda Kota Kupang No. 7/2000 (Kupang City's Green Space Regulation)	Art. 5 Par. (1)	"Penanaman vegetasi di RTH kota wajib menggunakan jenis-jenis asli Nusa Tenggara Timur ... untuk menjaga identitas ekologi lokal"	"Vegetation planting in city green spaces must use native East Nusa Tenggara species ... to preserve local ecological identity."

Note: This table is based on a systematic review of Indonesia's multi-tiered regulatory framework conducted to contextualize urban herbaceous conservation within the national legal landscape. Given Indonesia's decentralized governance system, regulations at the national, provincial, and municipal levels were examined to identify policy coherence and implementation gaps related to biodiversity conservation. The selected laws and regulations were identified through a screening process using three criteria: (i) relevance to urban spatial planning and green open space (RTH) management, (ii) explicit references to biodiversity conservation, native species use, or ecological function preservation, and (iii) jurisdictional authority over urban development in Kupang City. The reviewed framework indicates that biodiversity-sensitive urban planning is mandated across governance levels, with national regulations (e.g. PP 21/2021; UU 32/2024) establishing overarching principles, ministerial regulations (e.g. Permen ATR 14/2022; Permen PUPR 5/2008) providing operational guidance for native vegetation in RTH, and regional and municipal regulations (Perda 1/2011; Perda 12/2011; Perda 7/2000) emphasizing protection of high-biodiversity areas and local ecological identity. At the same time, the framework highlights continuing implementation challenges, particularly the absence of explicit provisions for conserving spontaneous urban vegetation in older local regulations

Table S2. Summary of recent Indonesian research (2020-2024) on urban flora

Author(s) (year)	Topics covered	Relevant direct quotations
Agustiyara et al. (2025)	(3) Urban Resilience	"The analysis of Urban Green Spaces (UGS) is fundamental for sustainable urban planning and enhancing the quality of life in densely populated Indonesian cities."
Gaol and Mudita (2022)	(1) Herbaceous Flora	"The research was conducted to determine the structure and composition of herbaceous species... The results showed that the savanna was dominated by herbaceous species, especially from the Poaceae family..."
Hanum et al. (2024)	(1) Herbaceous Flora, (3) Urban Resilience	"The results of the vegetation analysis showed that the plant community in the Green Open Spaces (GOS) of Surakarta City was dominated by herbaceous plants..." / "Green Open Spaces (GOS) play a crucial role in supporting biodiversity and providing ecological services in urban areas..."
Kiswantoro et al. (2024)	(3) Urban Resilience	"Community engagement through urban gardening and tree planting programs significantly contributes to mitigating the Urban Heat Island effect..."
Latifah et al. (2021)	(1) Herbaceous Flora, (3) Urban Resilience	"The undergrowth layer in the Udayana urban forest is rich in herbaceous species..." / "Conservation of urban forests is vital for maintaining native flora and supporting ecological stability in cities."
Putri et al. (2016)	(1) Herbaceous Flora	"The study documented various herbaceous species used as herbal medicine in the Ranggawulung Urban Forest..."
Santhyami et al. (2024)	(1) Herbaceous Flora, (3) Urban Resilience	"The market survey documented a variety of herbaceous plants traded for non-edible purposes..." / "The persistence of this trade underscores the role of urban markets in sustaining ethnobotanical knowledge..."
Safitri et al. (2024)	(1) Herbaceous Flora	"The study identified several wild herbaceous plants growing spontaneously in the residential environment that are used by the community as herbal medicine."

Note**:** This table synthesizes findings from ten peer-reviewed Indonesian studies published between 2020 and 2024 that examine the ecological and social roles of urban flora. The reviewed articles were selected based on three criteria: publication in reputable national or international journals, empirical focus on Indonesian urban settings, and relevance to herbaceous flora, spontaneous vegetation, or urban resilience. The summarized literature indicates that recent research predominantly addresses herbaceous flora in green open spaces and urban forests, its contribution to ecosystem services and climate adaptation, and its role in ethnobotanical practices within residential areas and urban markets. At the same time, the review highlights a notable gap in studies explicitly examining ruderal corridors (e.g. railway margins, vacant lots, drainage channels) as distinct landscape elements for urban biodiversity or ecological connectivity, suggesting that the socio-ecological significance of spontaneous urban vegetation remains underexplored in current Indonesian urban ecology research