

Article

Exploring Edible Underground Storage Organ Plants in Maha Sarakham Province, Thailand: Diversity, Traditional Uses, and Horticultural Importance

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Abstract

Edible underground storage organ (EUO) plants, including tubers, rhizomes, corms, and root tubers, play a crucial role in food security, nutrition, traditional medicine, and local livelihoods, yet many regions of northeastern Thailand, including Maha Sarakham Province, remain underexplored in ethnobotanical research. This study aimed to document the diversity, traditional uses, and economic importance of EUO plants in the province. Field surveys, local market assessments, and ethnobotanical interviews were conducted, and voucher specimens were collected. Quantitative indices, including the Cultural Food Significance Index (CFSI), Fidelity Level (%FL), and economic value (EV), were applied to evaluate the cultural, medicinal, and economic significance of each species. A total of 53 EUO taxa from 22 families were recorded, representing both wild-harvested and cultivated resources. Dioscoreaceae and Zingiberaceae were among the most species-rich families. Among the EUO plants, *Allium ascalonicum* L. stood out for its cultural significance, *Gloriosa superba* L. for its medicinal importance, and *Smallanthus sonchifolius* (Poepp.) H. Rob. for its economic value. Several other EUO plants exhibited high cultural consensus and consistent use patterns, underscoring their integration into local diets, traditional healthcare, and rural economies. The study demonstrates that EUO plants contribute not only to dietary diversity and cultural identity but also to rural economies. These findings highlight the importance of conserving biological and traditional knowledge and promote sustainable cultivation and horticultural development of priority EUO species to strengthen local food system resilience.

Keywords: Cultural Food Significance Index (CFSI); ethnobotany; Maha Sarakham Province; medicinal plants; Thailand; tuberous plants; underground storage organ plants



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1. Introduction

Underground storage organ plants—comprising bulbs, corms, rhizomes, taproot, roots, tuberous root, and tubers—represent an important yet often underappreciated component of the world's edible plant resources [1]. These organs serve as reservoirs for carbohydrates and other nutrients, enabling plants to survive adverse conditions and regenerate after dormancy [2]. For humans, they provide essential dietary staples, medicines, and horticultural crops that have sustained societies for millennia [3]. Globally, well-known edible underground storage organ (EUO) plants such as *Colocasia esculenta* (L.) Schott (taro), *Dioscorea* spp. (yams), *Ipomoea batatas* (L.) Lam. (sweet potato), and *Manihot esculenta* Crantz (cassava) play critical roles in food security, cultural identity, and economic development [4–7].

In traditional societies, edible underground organs are valued not only for their nutritional content but also for their cultural and medicinal roles. Many species are consumed as staple foods, snacks, or famine foods, while others are integral to traditional medicine and rituals [8,9]. Their underground nature also makes them resilient food sources during droughts or environmental stress, supporting household food security and adaptive strategies in rural areas [10]. Despite their ecological and cultural importance, ethnobotanical documentation of EUO plants remains incomplete, especially for wild or semi-cultivated species that have not been domesticated or commercialized.

Thailand, situated in the center of mainland Southeast Asia, possesses exceptional floristic diversity and deep-rooted ethnobotanical traditions. Edible underground plants form a vital part of Thai culinary and medicinal heritage, often prepared in soups, curries, or preserved as local delicacies [11]. In rural communities, especially in northeastern Thailand (Isan), people continue to gather and cultivate underground plant species for household consumption, traditional medicine, and local trade [12]. However, with the expansion of modern agriculture and declining dependence on forest resources, traditional knowledge associated with these plants is rapidly diminishing [13]. Documenting such knowledge is therefore crucial for both biocultural conservation and sustainable use.

Maha Sarakham Province, located in the Khorat Plateau of northeastern Thailand, provides an excellent setting to explore the ethnobotany of edible underground storage organ plants. The province is characterized by a tropical savanna climate, with distinct wet and dry seasons favoring the growth of geophytic plants that store nutrients underground [14]. The majority of residents engage in subsistence farming, integrating both cultivated and wild edible plants into their agroecosystems. Many EUO species—such as *Amorphophallus brevispathus* Gagnep., *Kaempferia marginata* Carey ex Roscoe, and *Pueraria candollei* Wall. ex Benth.—are commonly used as food and traditional medicine, reflecting a dynamic relationship between biodiversity, livelihood, and culture [15]. However, there is still limited scientific documentation on the diversity, distribution, and ethnobotanical uses of these plants in the province.

Previous ethnobotanical studies in Thailand have mainly focused on medicinal plants [16], wild edible plant [17], or specific plant families such as Zingiberaceae [18]. Very few have specifically addressed the diversity and utilization of EUO plants [19]. Such a gap limits our understanding of their potential contribution to sustainable agriculture, food resilience, and rural development. Considering the ongoing global challenges of biodiversity loss and climate change, identifying locally adapted and underutilized edible plants is increasingly vital for supporting community resilience and promoting agro-biodiversity [20].

Therefore, this study aims to document and analyze the diversity, traditional uses, and horticultural importance of edible underground storage organ plants in Maha Sarakham Province, Thailand. Specifically, it seeks to (1) record the species used for food and related purposes, (2) describe local knowledge regarding their preparation, cultural significance, and utilization, and (3) assess their potential for sustainable cultivation and horticultural

promotion. The results are expected to contribute to the ethnobotanical knowledge base of northeastern Thailand and provide scientific insights that support conservation strategies, local food system enhancement, and the valorization of underutilized plant resources.

2. Materials and Methods

2.1. Study Area

The study was conducted in Maha Sarakham Province, located in northeastern Thailand (approximate coordinates $15^{\circ}12'–16^{\circ}36' \text{ N}$, $102^{\circ}08'–103^{\circ}15' \text{ E}$) (Figure 1). The province covers an area of about 5000 km² [21]. The topography is predominantly a flat to gently undulating plain of the Khorat Plateau, with elevations generally ranging between 130 and 230 m above sea level [22].

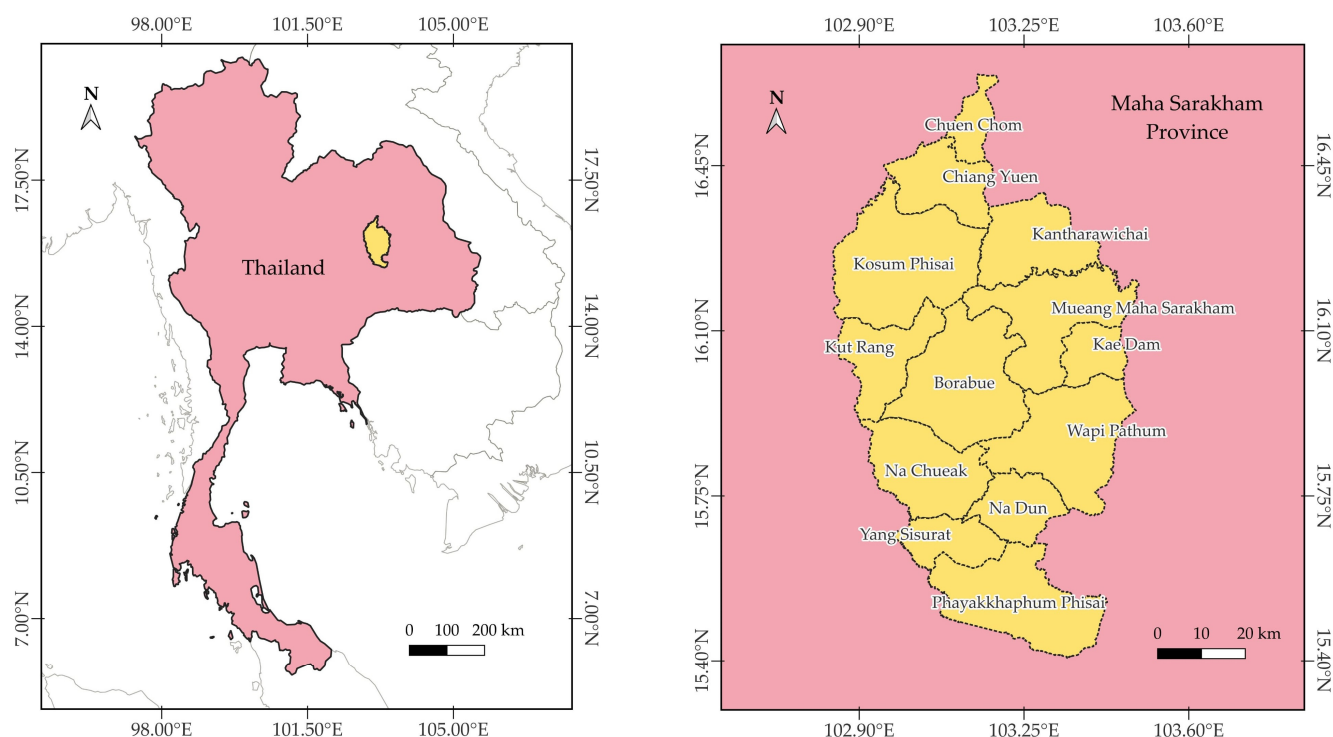


Figure 1. Map of the study area. The left panel shows Maha Sarakham Province highlighted in yellow within Thailand. The right panel presents Maha Sarakham Province divided into its 13 districts. (Map created using QGIS version 3.34 [23], geographic coordinate system: WGS 84, EPSG 4326; designed by Phiphat Sonthongphithak.).

Climatically, Maha Sarakham exhibits a tropical savanna climate (Köppen Aw), with three distinct seasons: a hot/dry season from February–April/May, a wet monsoon season from May/June–October, and a cooler dry season from November–February. Average annual rainfall is approximately 1200–1300 mm, and mean annual temperature is about 26.6 °C, with monthly mean highs exceeding 35 °C in the hot season [22].

Agriculture dominates the land-use in the province, especially rice cultivation across its expansive lowland plains, with smaller patches of upland, secondary forest, fallow lands and wetlands [24]. Given this mixture of agricultural, semi-natural and anthropogenic habitats, the province offers an ideal setting for investigating EUO plants under both wild and cultivated contexts.

Field surveys were conducted across representative districts of the province, sampling both low-lying rice-paddy dominated plains and marginal upland or fallow areas, in order to capture the full breadth of ecological variation, species diversity and cultural practices associated with EUO plants. Local informants—including farmers, foragers and market

vendors—were consulted for documentation of traditional knowledge, use-patterns and horticultural practices, thereby ensuring an integrated ecological, ethnobotanical and horticultural perspective to the study.

2.2. Plant Collection and Identification

Data collection was carried out over a 12-month period, from August 2024 to July 2025. The study focused on EUO plants occurring in both wild and cultivated settings, including home gardens, agricultural fields, fallow lands, and local markets across Maha Sarakham Province.

Specimens of all cited EUO species were collected during systematic field excursions and market surveys. For each species, detailed information was recorded, including local names, parts used, preparation methods, and observed traditional uses. Each plant was photographed in its natural or cultivated habitat, with particular attention to its underground organs, before being processed into herbarium vouchers. These vouchers were deposited in the Vascular Plant Herbarium, Mahasarakham University (VMSU), Kantharawichai District, Maha Sarakham Province, for long-term preservation.

Taxonomic identification was performed using standard botanical references, including the Flora of Thailand and other relevant regional taxonomic literature. Scientific names, family assignments, and current nomenclature were further verified through the Plants of the World Online database (<https://powo.science.kew.org>) (accessed on 15 July 2025) [25] and the World Flora Online (WFO) Plant List (<https://wfoplantlist.org/>) (accessed on 15 July 2025) [26]. Voucher specimens were annotated with collection data, habitat information, and ethnobotanical details to ensure comprehensive documentation of both botanical and cultural attributes of each EUO species.

2.3. Local Market Survey

To document the diversity, availability, and utilization of EUO plants in Maha Sarakham Province, a systematic survey of local markets was conducted from August 2024 to July 2025. The survey focused on community markets frequently visited by local residents and traders, where wild and cultivated EUO species are commonly sold or displayed, including fresh produce, dried materials, and processed plant products.

Data collection involved direct observation, structured interviews with market vendors, collectors, and local buyers, as well as photographic documentation of plant specimens and their products. For each recorded species, detailed information was obtained on the local name, plant part used, form of sale (whole plant, tuber, rhizome, corm, or processed form), seasonal availability, and local uses. In addition, data on selling price, source of the plant (wild-harvested or cultivated), and quantity sold per month were collected to evaluate the economic significance of each species in local markets.

Market surveys were conducted monthly to capture seasonal variation in species availability, trade frequency, and price fluctuation. All information was recorded in pre-designed data sheets, and the identities of informants were anonymized to ensure ethical compliance and data confidentiality.

This market-based approach provided a comprehensive understanding of the commercial importance, cultural relevance, and seasonal dynamics of EUO plants in Maha Sarakham Province, contributing valuable insight into their role in sustaining local livelihoods and promoting agrobiodiversity conservation.

2.4. Ethnobotanical Data Collection

Ethnobotanical fieldwork was conducted from August 2024 to July 2025 across 13 districts of Maha Sarakham Province, northeastern Thailand. The study employed a qualitative ethnobotanical approach, integrating semi-structured interviews, participant observa-

tion, and guided field walks with knowledgeable local informants to document traditional knowledge related to the utilization of EUO plants in both wild and cultivated contexts.

A semi-structured interview form was designed to facilitate comprehensive and systematic data collection. The questionnaire included both open-ended and structured questions focusing on local plant names, specific uses (food, medicinal, ritual, or other purposes), parts used, preparation and processing methods, and associated cultural or symbolic meanings. This design allowed informants to elaborate freely on traditional knowledge and local classification systems of EUO plants (Figure A1).

A total of 60 informants (30 men and 30 women, aged 25–75 years) were selected through purposive [27] and snowball sampling techniques [28], emphasizing local healers, experienced foragers, farmers, and individuals recognized within their communities for traditional plant knowledge (Table 1). Selection criteria included being a resident of the study area for at least 10 years, having direct experience in collecting, cultivating, or utilizing local EUO plants, and showing willingness to share knowledge. Interviews were conducted in Thai or the Isan dialect, depending on the informant's language preference.

Table 1. Demographic and cultural characteristics of survey locations, including GPS coordinates, gender distribution, ethnicity, language, and religion.

Location	GPS Coordinates		Gender		Ethnicity	Language	Religion
	Latitude (N, S)	Longitude (E, W)	M	F			
Borabue District	16°2'18" N	103°7'9" E	3	3	Lao Isan	Isan	Theravāda Buddhism, Christianity
Chiang Yuen District	16°24'29" N	103°6'19" E	2	2	Lao Isan	Isan	Theravāda Buddhism
Chuen Chom District	16°31'53" N	103°10'18" E	2	2	Lao Isan	Isan	Theravāda Buddhism
Kae Dam District	16°1'30" N	103°23'6" E	3	3	Lao Isan	Isan	Theravāda Buddhism
Kantharawichai District	16°19'22" N	103°17'48" E	2	2	Lao Isan	Isan	Theravāda Buddhism, Christianity
Kosum Phisai District	16°14'55" N	103°4'1" E	2	2	Lao Isan	Isan	Theravāda Buddhism
Kut Rang District	16°3'6" N	102°59'36" E	2	2	Lao Isan	Isan	Theravāda Buddhism
Mueang Maha Sarakham District	16°11'3" N	103°18'4" E	3	3	Lao Isan	Isan	Theravāda Buddhism, Christianity
Na Chueak District	15°48'0" N	103°1'54" E	3	3	Lao Isan	Isan	Theravāda Buddhism
Na Dun District	15°42'50" N	103°13'37" E	2	2	Lao Isan	Isan	Theravāda Buddhism
Phayakkhaphum Phisai District	15°30'59" N	103°11'37" E	2	2	Lao Isan	Isan	Theravāda Buddhism
Wapi Pathum District	15°50'48" N	103°22'48" E	2	2	Lao Isan	Isan	Theravāda Buddhism
Yang Sisurat District	15°41'24" N	103°6'12" E	2	2	Lao Isan	Isan	Theravāda Buddhism

Before each interview, the purpose, methods, and expected outcomes of the study were clearly explained to participants. In accordance with the International Society of Ethnobiology (ISE) Code of Ethics [29] and the Nagoya Protocol on Access and Benefit-Sharing [30], informed consent was obtained from all participants. Informants were assured of confidentiality, voluntary participation, and their right to withdraw at any stage without consequence.

Although this research did not involve sensitive personal data and therefore did not require formal institutional ethical approval, all field activities adhered to international standards of ethical ethnobotanical research, emphasizing respect, transparency, and reciprocal collaboration with local communities.

2.5. Data Analysis

2.5.1. Cultural Food Significance Index (CFSI)

The Cultural Food Significance Index (CFSI) was applied to evaluate the cultural importance of edible EUO and medicinal purposes. The index, originally proposed by

Pieroni [31], integrates seven ethnobotanical parameters into a single quantitative measure of a species' cultural significance, expressed as:

$$\text{CFSI} = \text{QI} \times \text{AI} \times \text{FUI} \times \text{PUI} \times \text{MFFI} \times \text{TSAI} \times \text{FMRI} \times 10^{-2} \quad (1)$$

where QI (Quotation Index) represents the proportion of informants who cited a species; AI (Availability Index) reflects the local abundance of the species, ranging from very common (4.0) to rare (1.0); FUI (Frequency of Utilization Index) quantifies how often the species is used, from more than once per week (5.0) to no longer used within 30 years (0.5); PUI (Parts Used Index) measures the diversity of plant parts utilized; MFFI (Multifunctional Food Use Index) evaluates the range of culinary applications such as boiling, roasting, or fermenting; TSAI (Taste Score Appreciation Index) assesses palatability from terrible (4.0) to excellent (10.0); and FMRI (Food–Medicinal Role Index) indicates the degree to which a plant functions as both a food and a medicinal resource, ranging from not recognized (1.0) to very high (5.0).

2.5.2. Cluster Analysis

A clustered heatmap was generated to visualize the relationships among utilization categories and medicinal properties of EUO plants. The analysis was performed using the online bioinformatics platform Bioinformatics (www.bioinformatics.com.cn) [32]. Data were uploaded in matrix format, and the tool's default parameters were applied, including hierarchical clustering based on Euclidean distance and complete linkage. The resulting heatmap allowed for the identification of similarity patterns and grouping structures among categories.

2.5.3. Informant Consensus Factor (F_{ic})

The Informant Consensus Factor (F_{ic}) was used to measure the degree of agreement among informants regarding the medicinal uses of EUO plants. This metric identifies ailment categories with high collective recognition and consistent use patterns. F_{ic} was calculated following Heinrich et al. [33] using the equation:

$$F_{ic} = \frac{n_{ur} - n_t}{n_{ur} - 1} \quad (2)$$

where n_{ur} is the total number of use reports for each ailment category and n_t is the number of species cited in that category. F_{ic} values range from 0 to 1, with values close to 1 indicating strong consensus among informants. High F_{ic} values suggest that specific ailments are well known and treated with widely trusted plant remedies.

2.5.4. Fidelity Level (%FL)

The Fidelity Level (FL) was applied to assess the degree to which a plant species is specifically associated with a particular medicinal use. This index provides insight into the cultural reliability and therapeutic specificity of traditional plant knowledge. FL was calculated according to Friedman et al. [34] using the formula:

$$\text{FL} = \frac{I_p}{I_u} \times 100 \quad (3)$$

where I_p represents the number of informants citing a species for a specific ailment and I_u is the total number of informants who mentioned that species for any medicinal use. Higher FL values indicate that most informants consistently associate the species with a single therapeutic purpose, reflecting strong cultural agreement.

2.5.5. Economic Value Assessment

An Economic Value (EV) assessment was conducted to evaluate the contribution of EUO plants to local livelihoods in Maha Sarakham Province. Quantitative market data were integrated with verified botanical identifications to ensure accurate recognition of traded species. Monthly surveys from August 2024 to July 2025 recorded market prices, sale quantities, and seasonal availability.

The annual economic value of each species was estimated following the method of Phatlamphu et al. [35], using the equation:

$$EV = AP \times SM \times SP \quad (4)$$

where EV denotes the annual economic value (THB), AP is the average market price per kilogram (THB/kg), SM represents the average monthly sales volume (kg), and SP is the number of months each species was available for sale during the study period. The resulting EV reflects the total annual income derived from the trade of EUO species, highlighting their economic significance and role in supporting rural sustainability.

3. Results

3.1. Diversity of EUO Plants in Maha Sarakham Province

A total of 53 taxa belonging to 33 genera and 22 families of EUO plants were recorded in Maha Sarakham Province (Table 2). The family Zingiberaceae was the most represented, accounting for 18 taxa (33.94%), followed by Dioscoreaceae with 7 taxa (13.20%), and Amaryllidaceae and Araceae, each with 3 taxa (5.66%). Families such as Asteraceae, Cyperaceae, Fabaceae, and Smilacaceae were represented by 2 taxa each (3.77%), whereas the remaining 14 families, including Amaranthaceae, Apiaceae, Brassicaceae, Cannaceae, Colchicaceae, Convolvulaceae, Costaceae, Euphorbiaceae, Marantaceae, Menispermaceae, Nelumbonaceae, Orobanchaceae, Solanaceae, and Stemonaceae, were represented by a single taxon each (1.89%).

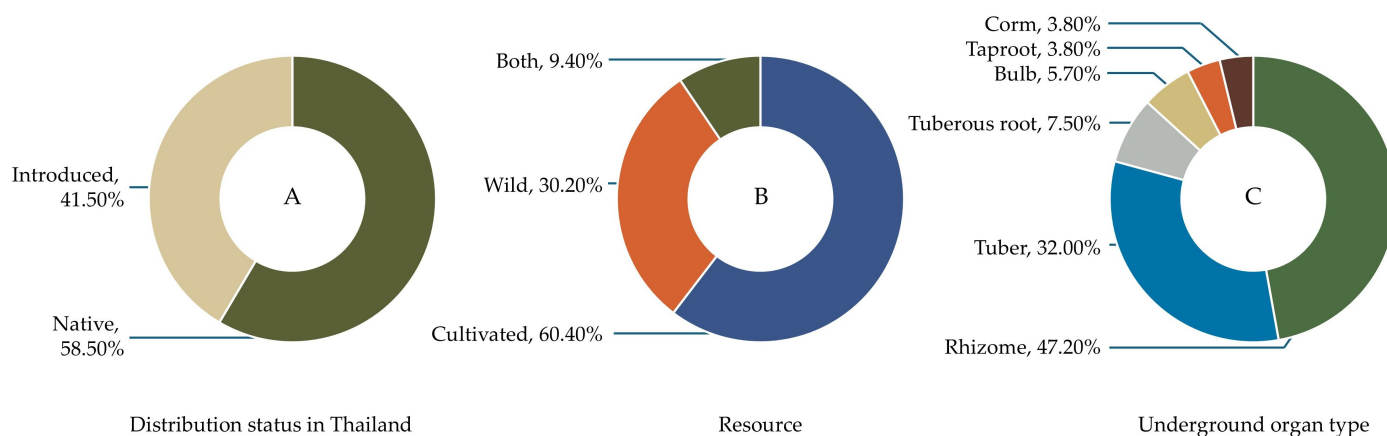


Figure 2. Pie charts showing the percentage distribution of EUO plants in Maha Sarakham Province, Thailand, according to (A) distribution status in Thailand, (B) resource, and (C) underground organ type.

In terms of underground organ types, the majority were rhizomes (25 taxa, 47.20%), followed by tubers (17 taxa, 32.00%), tuberous roots (4 taxa, 7.50%), bulbs (3 taxa, 5.70%), and both corms and taproots (2 taxa each, 3.80%) (Figure 2).

Table 2. Edible underground storage organ plants in Maha Sarakham Province, Thailand, with family, scientific name, vernacular name, distribution in Thailand (DiT), resource, under-ground storage organ type (USO), used parts, utilization, preparation methods, and voucher number (VN).

Family	Scientific Name	Vernacular Name	DiT	Resource	USO	Used Parts	Utilization	Method of Uses	VN
Amaranthaceae	<i>Beta vulgaris</i> subsp. <i>vulgaris</i> “Conditiva Group”	บีทรูท (Bit Rut)	In	Cv	Tuberous root	Tr	BV, VB	Blended into beverages or consumed fresh as salad vegetables.	TJ645
						Bu	CF	Used in cooking to enhance aroma and pungency.	
Amaryllidaceae	<i>Allium ascalonicum</i> L.	หอมแดง (Hom Daeng)	In	Cv	Bulb	Bu, Lf	FP	Used for making pickled vegetables.	TJ638
						Lf	VB	Eaten fresh or incorporated into stir-fried, boiled, steamed, or fried dishes.	
						Ir	VB	Used in stir-fried dishes.	
	<i>Allium cepa</i> L.	หอมหัวใหญ่ (Hom Hua Yai)	In	Cv	Bulb	Bu	VB	Used in stir-fried and boiled dishes.	TJ639
	<i>Allium sativum</i> L.	กระเทียม (Krathiam)	In	Cv	Bulb	Bu	CF, FP	Used to enhance aroma in cooking and for preparing pickled vegetables.	TJ640
						Ir	VB	Used in stir-fried dishes.	
Apiaceae	<i>Daucus carota</i> subsp. <i>sativus</i> (Hoffm.) Schübl. & G.Martens	แครอท (Carrot)	In	Cv	Taproot	Tt	BV, VB	Blended into beverages, boiled or consumed fresh in salads, and used in stir-fried or boiled dishes.	TJ680
Araceae	<i>Amorphophallus paeoniifolius</i> (Dennst.) Nicolson	อีบุค (I Buk)	Nt	Wd	Tuber	Tb	VB	Peeled, cut into small pieces, boiled until cooked, then mashed and allowed to set into a jelly-like consistency before being used in cooking.	TJ644
	<i>Colocasia esculenta</i> (L.) Schott “Giant elephant ear”	ทุ่น (Thun)	Nt	Wd	Corm	Cm, Lf	VB	Boiled or roasted prior to cooking to reduce irritation.	TJ648
	<i>Colocasia esculenta</i> (L.) Schott “Taro”	เผือก (Phueak)	Nt	Cv	Corm	Cm	SF, SW	Used in the preparation of desserts or boiled and consumed as a staple food.	TJ649
Asteraceae	<i>Helianthus tuberosus</i> L.	แก่งตะวัน (Kaen Tawan)	In	Cv	Tuber	Tb	ME	Used for medicinal purposes.	TJ653
	<i>Smallanthus sonchifolius</i> (Poepp.) H.Rob.	บัวหิมะ (Bua Hima)	In	Cv	Tuber	Tb	SW	Eaten fresh as a snack.	TJ663
Brassicaceae	<i>Raphanus raphanistrum</i> subsp. <i>sativus</i> (L.) Schmalh.	หัวไชเท้า (Hua Chai Thao)	In	Cv	Taproot	Tt	VB	Used in boiled dishes.	TJ662
Cannaceae	<i>Canna indica</i> L. “Australian arrowroot”	มันสาธุพุทธรักษา (Man Sakhu Phuttharaksa)	In	Cv	Rhizome	Rm	SW	Boiled and consumed as a snack or used in the preparation of desserts.	TJ647
Colchicaceae	<i>Gloriosa superba</i> L.	ดองดึง (Dong Dueng)	In	Bt	Tuber	Tb	ME	Used for medicinal purposes.	TJ688
Convolvulaceae	<i>Ipomoea batatas</i> (L.) Lam.	มันเทศ (Manthet)	In	Cv	Tuber	Tb	SF, SW	Boiled, steamed, or roasted and consumed as a staple food, snack, or dessert ingredient.	TJ655

Table 2. Cont.

Family	Scientific Name	Vernacular Name	DiT	Resource	USO	Used Parts	Utilization	Method of Uses	VN
Costaceae	<i>Hellenia speciosa</i> (J.Koenig) S.R.Dutta	เอื้องหมอยนา (Ueang Mai Yana)	Nt	Bt	Rhizome	Sh	VB	The tender stem is used in boiled dishes.	TJ654
						Rm	ME	Used for medicinal purposes.	
Cyperaceae	<i>Cyperus rotundus</i> L.	หญ้าหน้ำหนู (Ya Haeomu)	Nt	Wd	Tuber	Tb	ME	Used for medicinal purposes.	TJ679
	<i>Eleocharis dulcis</i> (Burm.f.) Trin. ex Hensch.	แห้ว (Haeo)	Nt	Cv	Tuber	Tb	SW	Consumed as a snack or used in desserts.	TJ686
Dioscoreaceae	<i>Dioscorea alata</i> L.	มันเสา (Man Sao)	Nt	Wd	Tuber	Tb	SW	Used in the preparation of desserts.	TJ681
	<i>Dioscorea bulbifera</i> L.	อีลุมปุมเป้า (I Lum Pum Pao)	Nt	Wd	Tuber	Tb	ME	Used for medicinal purposes.	TJ669
	<i>Dioscorea esculenta</i> (Lour.) Burkill	มันมือเสือ (Man Mue Suea)	Nt	Bt	Tuber	Tb	SW	Used in the preparation of desserts.	TJ682
	<i>Dioscorea filiformis</i> Blume	มันเทียน (Man Thian)	Nt	Wd	Tuber	Tb	SF, SW	Boiled and consumed as a snack or used in the preparation of desserts.	TJ683
	<i>Dioscorea hispida</i> Dennst.	กลอย (Kloi)	Nt	Wd	Tuber	Tb	SF, SW	Peeled, sliced thinly, soaked in water to reduce irritation, then steamed and used in desserts.	TJ684
	<i>Dioscorea pseudotomentosa</i> Prain & Burkill	๑๑๑๑๑๑ (Man Saeng)	Nt	Wd	Tuber	Tb	SF, SW	Boiled and consumed as a snack or used in desserts.	TJ685
	<i>Tacca leontopetaloides</i> (L.) Kuntze	เห้ายายหม่อม (Thaoyaimom)	Nt	Wd	Tuber	Tb	SF, SW	Used in food or dessert preparation; preparation method: peeled, washed, cut into small pieces, finely ground, and filtered through muslin cloth to obtain starch water, allowed to settle for 2–3 cycles, and the resulting starch sediment is dried for later use.	TJ670
Euphorbiaceae	<i>Manihot esculenta</i> Crantz	มันสำปะหลัง (Mansampalang)	In	Cv	Tuberous root	Tr	SW	Boiled or roasted and consumed as a snack or used in desserts.	TJ657
Fabaceae	<i>Pachyrhizus erosus</i> (L.) Urb.	มันแกว (Man Kaeo)	In	Cv	Tuberous root	Tr	SW	Eaten fresh as a snack or used in desserts.	TJ660
	<i>Pueraria mirifica</i> Airy Shaw & Suvat.	กวาวเครือขาว (Kwao Khrua Khao)	Nt	Cv	Tuberous root	Tr	ME	Used for medicinal purposes.	TJ661
Marantaceae	<i>Maranta arundinacea</i> L.	มันสาหุ (Man Sakhu)	In	Cv	Rhizome	Rm	SW	Boiled and consumed as a snack.	TJ658
Menispermaceae	<i>Stephania venosa</i> (Blume) Spreng.	สมุนไพร (Sabu Lueat)	Nt	Cv	Tuber	Tb	ME	Used for medicinal purposes.	TJ668
Nelumbonaceae	<i>Nelumbo nucifera</i> Gaertn.	บัวหลวง (Bua Luang)	Nt	Bt	Rhizome	Rm	SW, VB	Rhizome: Used in desserts or incorporated into boiled and stir-fried dishes	TJ659
						Sh	VB	Used in stir-fried dishes.	
Orobanchaceae	<i>Aeginetia indica</i> L.	ดอกดิน (Dokdin)	Nt	Wd	Rhizome	Ir	CF	Squeezed with water, filtered to obtain the colored liquid, and mixed with sticky rice to enhance coloration.	TJ637
						Rm	ME	Used for medicinal purposes	

Table 2. Cont.

Family	Scientific Name	Vernacular Name	DiT	Resource	USO	Used Parts	Utilization	Method of Uses	VN
Smilacaceae	<i>Smilax corbularia</i> Kunth	ข้าวเย็นเหนือ (Khao Yen Nuea)	Nt	Wd	Rhizome	Rm	ME	Used for medicinal purposes.	TJ664
	<i>Smilax glabra</i> Roxb.	ข้าวเย็นใต้ (Khao Yen Tai)	Nt	Wd	Rhizome	Rm	ME	Used for medicinal purposes.	TJ665
Solanaceae	<i>Solanum tuberosum</i> L.	มันฝรั่ง (Manfarang)	In	Cv	Tuber	Tb	SF	Boiled and consumed as a staple food.	TJ666
Stemonaceae	<i>Stemona collinsiae</i> Craib	หนอนดาวยาก (Non Tai Yak)	Nt	Wd	Tuber	Tb, Rt	ME	Used for medicinal purposes.	TJ667
Zingiberaceae	<i>Alpinia conchigera</i> Griff.	ข่าลิง (Kha Ling)	Nt	Wd	Rhizome	Rm	ME	Used for medicinal purposes.	TJ641
	<i>Alpinia galanga</i> (L.) Willd.	ข่าตาแดง (Kha Tadaeng)	Nt	Cv	Rhizome	Rm	CF	Used in cooking to enhance aroma and pungency.	TJ642
						Ir	VB	Eaten fresh or boiled and consumed as a vegetable with chili paste.	
	<i>Alpinia siamensis</i> K.Schum.	ข่าบ้าน (Kha Ban)	Nt	Cv	Rhizome	Rm	CF	Used in cooking to enhance aroma and pungency.	TJ643
						Ir	VB	Eaten fresh or boiled and consumed as a vegetable with chili paste.	
	<i>Boesenbergia rotunda</i> (L.) Mansf.	กระชาย (Kra Chai)	Nt	Cv	Rhizome	Rm	CF	Used in cooking to enhance aroma and pungency.	TJ646
	<i>Curcuma angustifolia</i> Roxb.	กระเจียวแดง (Kra Chiao Daeng)	Nt	Bt	Rhizome	Ir	VB	Eaten fresh or boiled as a vegetable with chili paste.	TJ650
						Ir, Rm	ME	Used for medicinal purposes.	
	<i>Curcuma longa</i> L.	ขมิ้นชัน (Khamin Chan)	In	Cv	Rhizome	Rm	ME	Used for medicinal purposes.	TJ651
	<i>Curcuma mangga</i> Valetton & Zijp	ขมิ้นขาว (Khamin Khao)	In	Cv	Rhizome	Rm	VB	Rhizome: Eaten fresh as a vegetable with chili paste.	TJ652
	<i>Curcuma singularis</i> Gagnep.	กระเจียวขาว (Kra Chiao Khao)	Nt	Wd	Rhizome	Ir	VB	Eaten fresh or boiled as a vegetable with chili paste.	TJ676
						Rm	ME	Used for medicinal purposes.	
	<i>Curcuma zanthorrhiza</i> Roxb.	ขมิ้นชันมดลูก (Wan Chak Motluk)	In	Cv	Rhizome	Rm	ME	Used for medicinal purposes.	TJ677
	<i>Curcuma zedoaria</i> (Christm.) Roscoe	ขมิ้นอ้อย (Khamin Oi)	In	Cv	Rhizome	Rm	ME	Used for medicinal purposes.	TJ678
	<i>Etlingera elatior</i> (Jack) R.M.Sm.	ดาหลา (Da La)	Nt	Cv	Rhizome	Ir	VB	Used in spicy salad preparations.	TJ687
						Rm	ME	Used for medicinal purposes.	
	<i>Hedychium coronarium</i> J.Koenig	สเลเต (Sa Le Te)	Nt	Cv	Rhizome	Ir	VB	Used in boiled dishes.	TJ689
						Rm	ME	Used for medicinal purposes.	
	<i>Kaempferia marginata</i> Carey ex Roscoe	ตูปมูบ (Tup Mup)	Nt	Wd	Rhizome	Lf	ME, VB	Eaten fresh or incorporated into boiled dishes or spicy salads.	TJ656
						Rm		Used for medicinal purposes.	

Table 2. Cont.

Family	Scientific Name	Vernacular Name	DiT	Resource	USO	Used Parts	Utilization	Method of Uses	VN
	<i>Zingiber ligulatum</i> Roxb.	ชิงแห้ง (Khinghaeng)	In	Cv	Rhizome	Rm	ME	Used for medicinal purposes.	TJ671
	<i>Zingiber officinale</i> Roscoe	ชิง (Khing)	In	Cv	Rhizome	Rm	CF, FP	Used in cooking to enhance pungency, incorporated into dipping sauces, and used in the preparation of pickled vegetables.	TJ672
						Lf	VB	Eaten fresh as a vegetable with chili paste.	
	<i>Zingiber ottensii</i> Valeton	ไพลดำ (Phlai Dam)	In	Cv	Rhizome	Rm	ME	Used for medicinal purposes.	TJ673
	<i>Zingiber purpureum</i> Roscoe	ไพล (Phlai)	In	Cv	Rhizome	Rm, Lf	ME	Used for medicinal purposes.	TJ674
	<i>Zingiber zerumbet</i> (L.) Roscoe ex Sm.	กระเทียม (Kra Thue)	Nt	Cv	Rhizome	Ir	ME	Eaten as a vegetable with chili paste.	TJ675
						Rm		Used for medicinal purposes.	

Abbreviation. Distribution in Thailand: In (introduced), Nt (native). Resource: Bt (both), Cv (cultivated), Wd (wild). Used parts: Bu (bulb), Cm (corm), Ir (inflorescence), Lf (leaf), Rm (rhizome), Rt (root), Sh (shoot), Tb (tuber), Tr (tuberous root), Tt (taproot). Utilization; BV (beverage), CF (condiments and flavoring), FP (fermented or preserved), ME (medicinal edible plant), SF (staple food), SW (sweet, dessert, or snack), VB (vegetable). The recorded EUO plants in Maha Sarakham Province comprised 31 native taxa (58.50%) and 22 introduced taxa (41.50%). Regarding their resource status, 32 taxa (60.40%) were cultivated, 16 taxa (30.20%) were collected from the wild, and 5 taxa (9.40%) occurred in both cultivated and wild habitats (Figure 2).

The analysis of plant parts used in EUO species (Figure 3) revealed that the rhizome was the most frequently utilized part, accounting for 35.70% of all uses, followed by tubers (24.30%) and inflorescences (14.30%). Other parts were used less frequently, including leaves (7.10%), tuberous roots (5.70%), bulbs (4.30%), corms (2.90%), shoots (2.90%), roots (1.40%), and taproots (1.40%).

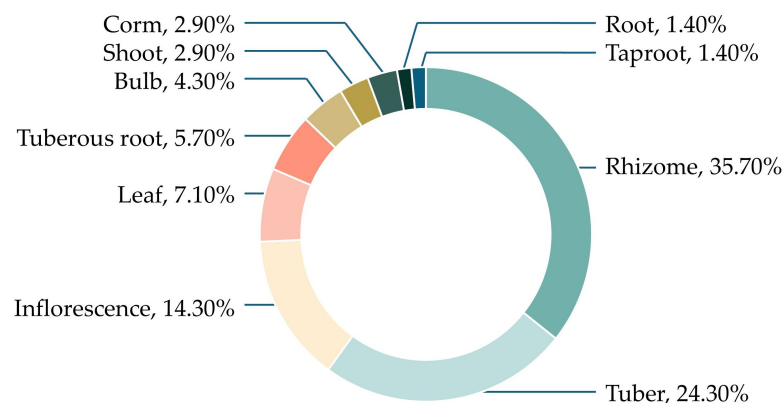


Figure 3. Pie charts showing the percentage distribution of plant parts used in EUO plants in Maha Sarakham Province, Thailand.

3.2. Utilization of EUO Plants

3.2.1. EUO Plants Used as Beverage

Two EUO taxa were recorded as ingredients in beverages among local communities (Table 1). These taxa belong to the families Amaranthaceae and Apiaceae and are widely integrated into daily diets not only for their flavor but also for their perceived nutritional benefits (Table 2).

Beta vulgaris subsp. *vulgaris* “Conditiva Group” (Amaranthaceae) was frequently used for preparing blended drinks due to its sweet taste and vibrant coloration. Its tuberous root was also occasionally consumed fresh as a salad vegetable. In contrast, *Daucus carota* subsp. *sativus* (Apiaceae) was used more diversely. The taproot was commonly blended into beverages, but it was also eaten fresh in salads, boiled, or incorporated into stir-fried dishes, reflecting its versatility and widespread culinary acceptance.

Overall, these two taxa illustrate how cultivated EUO plants contribute not only to household nutrition but also to culturally embedded beverage practices within the study area.

3.2.2. EUO Plants Used as Condiments or Flavoring

Seven EUO plant species from the families Amaryllidaceae, Orobanchaceae, and Zingiberaceae were recorded as condiments and flavoring materials (Table 2).

In Amaryllidaceae, *Allium ascalonicum* and *A. sativum* were the main aromatic plants used in cooking. The bulbs of both species were added to dishes to improve aroma and pungency. *A. ascalonicum* was used in several ways: its bulbs and leaves were included in pickled vegetables, its inflorescences were added to stir-fried dishes, and its leaves were eaten fresh or cooked. *A. sativum* was also used for its bulbs in cooked foods and pickling, and its inflorescences were used in stir-fried dishes.

Four species of Zingiberaceae were recorded. The rhizomes of *Alpinia galanga* and *A. siamensis* were used to add aroma and pungency to foods, and their inflorescences were eaten fresh or boiled and consumed with chili paste. *Boesenbergia rotunda* was used mainly for its pungent rhizome. *Zingiber officinale* was used for its rhizome in cooked foods, dipping sauces, and pickled preparations, and its young leaves were eaten fresh with chili paste.

Aeginetia indica (Orobanchaceae) was the only species in this family. Its inflorescences were squeezed with water and filtered to obtain a natural coloring liquid mixed with sticky rice. The plant was also noted for medicinal use.

These species illustrate the range of EUO plants used to improve aroma, flavor, and color in local cuisine.

3.2.3. EUO Plants Used as Fermented or Preserved

Three species were recorded in the fermented or preserved food category, belonging to the families Amaryllidaceae and Zingiberaceae (Table 2). Both *Allium ascalonicum* and *A. sativum* were commonly used in pickled vegetable preparations. In *A. ascalonicum*, the bulbs and leaves were used for pickling. *A. sativum* was used primarily for its bulbs for cooking and in pickled vegetables.

Zingiber officinale—The rhizome was used in the preparation of pickled vegetables and were commonly eaten with *Sai Krok Isan* (Isan sausage).

3.2.4. EUO Plants Used as Medicinal Edible Plants

A total of 24 EUO plant species from 11 families were recorded as medicinal edible plants in the study area (Table 2 and Figure 4). The family Zingiberaceae was the most represented, comprising 13 species, followed by Smilacaceae with 2 species. The remaining families—Asteraceae, Colchicaceae, Costaceae, Cyperaceae, Dioscoreaceae, Fabaceae, Menispermaceae, Orobanchaceae, and Stemonaceae—were each represented by a single species. Detailed information on the ethnomedicinal uses of these species is provided in the ethnomedicinal of EUO plants section.

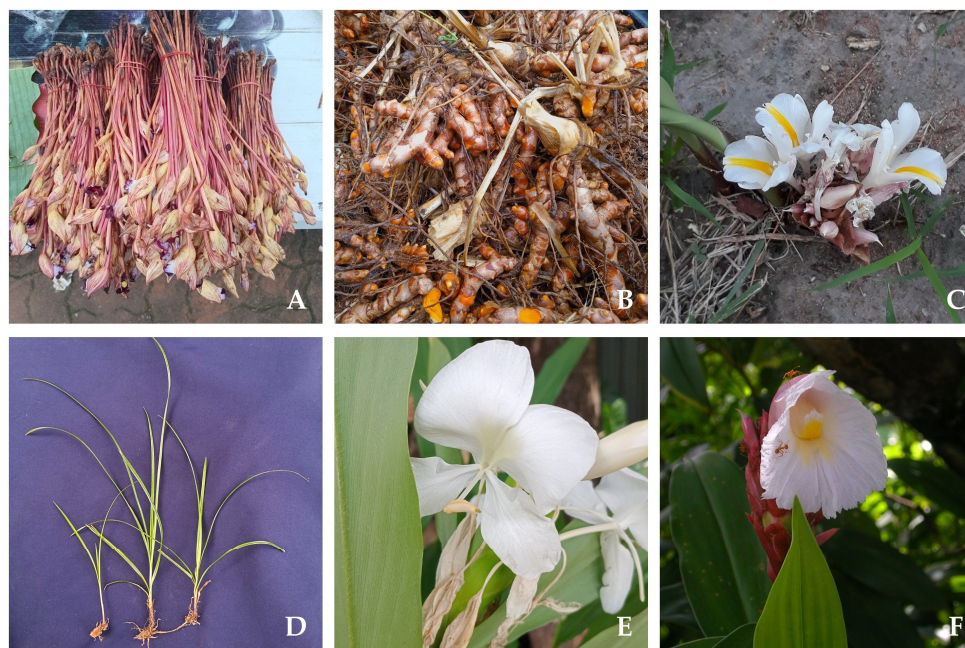


Figure 4. Examples of EUO plants used as medicinal edible plants: (A) *Aeginetia indica* L.; (B) *Curcuma longa* L.; (C) *Curcuma singularis* Gagnep.; (D) *Cyperus rotundus* L.; (E) *Hedychium coronarium* J.Koenig; (F) *Hellenia speciosa* (J.Koenig) S.R.Dutta (photographs: (A,B,D,E) by Tammanoon Jitpromma; (C,F) by Surapon Saensouk).

3.2.5. EUO Plants Used as Staple Food

Seven species from four families were recorded as EUO plants used as staple foods (Table 2). In Araceae, *Colocasia esculenta* “Taro” was used for its corm, which was boiled and consumed as a staple food. In Convolvulaceae, *Ipomoea batatas* was consumed after boiling, steaming, or roasting, and used as a staple food.

Members of Dioscoreaceae included *Dioscorea filiformis*, *D. hispida*, and *D. pseudotomentosa*, all primarily used as tubers. *D. filiformis* and *D. pseudotomentosa* were boiled and consumed as staple food, snacks or used in desserts. *D. hispida* required peeling, slicing, and soaking in water to reduce irritation before steaming and inclusion in desserts. *Tacca leontopetaloides* was prepared by peeling, washing, cutting, grinding, and filtering the tubers to obtain starch, which was dried and used in food or dessert preparation.

Finally, Solanaceae was represented by *Solanum tuberosum*, which was boiled and consumed as a staple food. These species highlight the importance of EUO plants in providing carbohydrates and serving as essential components of the local diet.

3.2.6. EUO Plants Used as Sweets, Desserts, or Snacks

A total of 15 species from 10 families were recorded as EUO plants used as sweets, desserts, or snacks (Table 2). The edible parts were mainly tubers, corms, rhizomes, or pseudostems, and preparation methods included boiling, steaming, roasting, grinding, or processing into starch for later use.

Species from Araceae, Asteraceae, Cannaceae, Convolvulaceae, and Cyperaceae were used individually as snacks or desserts. *Colocasia esculenta* (Araceae)—corms were boiled or used in desserts. *Smallanthus sonchifolius* (Asteraceae)—tubers eaten fresh as a snack. *Canna indica* (Cannaceae)—rhizomes boiled and consumed as a snack or in desserts. *Ipomoea batatas* (Convolvulaceae)—tubers boiled, steamed, or roasted and used as snacks or in desserts. *Eleocharis dulcis* (Cyperaceae)—tubers eaten as a snack or included in desserts.

Several Dioscoreaceae species (*Dioscorea alata*, *D. esculenta*, *D. filiformis*, and *D. pseudotomentosa*)—tubers boiled and consumed as snacks or used in desserts. *D. hispida*—steamed and used in desserts. *Tacca leontopetaloides* (Stemonaceae)—tubers processed to obtain starch for use in foods or desserts.

Other families included Euphorbiaceae, Fabaceae, Marantaceae, and Nelumbonaceae. *Manihot esculenta* (Euphorbiaceae)—tuberous roots boiled or roasted for snacks or desserts; *Pachyrhizus erosus* (Fabaceae)—tuberous roots eaten fresh or in desserts; *Maranta arundinacea* (Marantaceae)—rhizomes boiled as a snack; *Nelumbo nucifera* (Nelumbonaceae)—rhizomes used in desserts or cooked dishes, with pseudostems incorporated into stir-fried preparations.

These species illustrate the diversity of EUO plants used for sweets, desserts, and snacks, highlighting both the edible part and preparation methods in local culinary practices (Figure 5).



Figure 5. Examples of EUO plants used as sweets, desserts, or snacks: (A) *Eleocharis dulcis* (Burm.f.) Trin. ex Hensch. eaten as snack; (B) flower of *Ipomoea batatas* (L.) Lam.; (C) *Ipomoea batatas* (L.) Lam. grilled for snack; (D) *Pachyrhizus erosus* (L.) Urb. (photographs: (A,C) by Tammanoon Jitpromma; (B,D) by Surapon Saensouk).

3.2.7. EUO Plants Used as Vegetables

A total of 19 taxa from 8 families were recorded as EUO plants used as vegetables in local diets (Table 2). The edible parts included tubers, corms, rhizomes, leaves, inflorescences, pseudostems, and bulbs, which were prepared by boiling, roasting, steaming, or incorporating into salads, stir-fried, or spicy dishes.

Araceae was represented by *Amorphophallus paeoniifolius*—tubers peeled, cut, boiled, and mashed into a jelly-like consistency; and *Colocasia esculenta*—corms and leaves boiled or roasted to reduce irritation before consumption. In Amaranthaceae and Apiaceae, *Beta vulgaris* subsp. *vulgaris*—tuberous roots were consumed fresh or blended into beverages, and *Daucus carota* subsp. *sativus*—taproots boiled, used in salads, or stir-fried. Brassicaceae (*Raphanus raphanistrum* subsp. *sativus*)—taproots were used in boiled dishes.

Amaryllidaceae species, including *Allium ascalonicum*, *A. cepa*, and *A. sativum*, were used for their bulbs, leaves, and inflorescences, either in cooking to enhance aroma and pungency, for pickled vegetables, or in stir-fried dishes. Costaceae (*Hellenia speciosa*)—tender pseudostems were boiled, with additional medicinal use. Nelumbonaceae (*Nelumbo nucifera*)—rhizomes and pseudostems incorporated into desserts, boiled, or stir-fried.

Most species belonged to Zingiberaceae, with rhizomes, leaves, or inflorescences consumed fresh, boiled, or added to spicy salads. Notable examples included *Alpinia galanga*, *A. siamensis*, *Curcuma angustifolia*, *C. mangga*, *C. singularis*, *Etlingera elatior*, *Hedychium coronarium*, *Kaempferia marginata*, and *Zingiber officinale*, many of which were also recognized for medicinal uses. Rhizomes were commonly added to enhance aroma and pungency, while leaves and inflorescences were eaten fresh or boiled with chili paste or incorporated into spicy salads and boiled dishes.

These species highlight the diversity of EUO plants used as vegetables, reflecting the integration of multiple edible parts and preparation methods in local culinary practices.

3.2.8. Toxic or Potentially Harmful of EUO Plants

Several EUO plants documented in this study possess toxic properties or contain bioactive compounds that require specific preparation methods to ensure safe use. Although these species are traditionally consumed or applied for medicinal purposes, improper handling or inadequate processing can lead to adverse effects ranging from mild irritation to severe systemic toxicity. Understanding the toxic parts, types of harmful compounds, and culturally embedded detoxification techniques is therefore essential to ensure both safety and the continuation of traditional knowledge systems. The toxic characteristics and recommended detoxification methods for each species are summarized in Table 3.

Table 3. Toxic or potentially harmful properties of EUO plants and traditional detoxification methods.

Scientific Name	Toxic or Harmful Components and Detoxification Methods
<i>Amorphophallus paeoniifolius</i> (Dennst.) Nicolson	The tuber contains calcium oxalate crystals, which can cause irritation, burning sensation, and swelling of the mouth and throat if consumed raw. Detoxification typically involves peeling, cutting into small pieces, and boiling thoroughly. In some cases, prolonged cooking or combining with acidic or alkaline ingredients (e.g., tamarind, lime water) is used to further reduce irritation [36].
<i>Colocasia esculenta</i> (L.) Schott “Giant elephant ear”	Similarly to other Araceae members, the corms and leaves contain calcium oxalate crystals capable of causing mucosal irritation. Traditional preparation involves peeling and boiling or roasting before use, which helps break down oxalate crystals and reduce acidity [37].
<i>Dioscorea hispida</i> Dennst.	The tubers contain high levels of alkaloids, including dioscorine, which can cause dizziness, nausea, and neurotoxicity when improperly prepared. Detoxification requires peeling, slicing thinly, and soaking the tubers in running water or repeatedly changing water for several hours to remove toxins, followed by steaming or boiling before consumption [38].
<i>Gloriosa superba</i> L.	All parts of the plant contain highly toxic alkaloids, including colchicine, superbrine, gloriosine, chelidonic acid, and salicylic acid, which can induce severe gastrointestinal distress, multi-organ failure, or even death at low doses. Although the tubers have been traditionally reported for medicinal use in some regions, they are not consumed as food due to their extreme toxicity, and no reliable detoxification method is available. Any medicinal application of this species should be conducted only under the supervision of qualified professionals [39].
<i>Manihot esculenta</i> Crantz	The tuberous roots contain cyanogenic glycosides (linamarin and lotaustralin), which release hydrogen cyanide when inadequately processed. Bitter cultivars are especially hazardous. Standard detoxification involves peeling, grating or slicing, followed by washing, soaking, and thorough cooking (boiling or roasting). Sun-drying or fermentation is also employed traditionally to reduce cyanide levels [40].
<i>Stemona collinsiae</i> Craib	The roots contain alkaloids such as stemonine and stemonidine, which may cause nausea or respiratory depression if ingested in large quantities. Although primarily used medicinally rather than as food, proper preparation involves controlled dosing, decoction, and avoidance of raw consumption [41].

3.3. Cultural Food Significance Index (CFSI) of EUO Plants

The quantitative evaluation of 53 EUO taxa in Pa Tio District using the Cultural Food Significance Index (CFSI) revealed clear patterns in their cultural and dietary importance (Table S1). The EUO species were grouped according to their CFSI values to identify those most frequently used and culturally embedded in local food traditions.

Species with the highest importance values ($\text{CFSI} > 500$) included *Allium ascalonicum*, *A. sativum*, *Alpinia siamensis*, *Boesenbergia rotunda*, *Daucus carota* subsp. *sativus*, and *Kaempferia marginata* and representing primarily vegetables and aromatic rhizomes. These species are central to traditional diets, providing flavor, and nutrition. *A. ascalonicum* and *A. sativum* have long been consumed in a variety of dishes, while species such as *Alpinia siamensis* and *Boesenbergia rotunda* are commonly used as seasonings and condiments in daily cooking. The high CFSI values of these species were supported by consistently strong scores across contributing indices, including high availability (AI), frequency of utilization (FUI), number of parts used (PUI), multifunctional food use (MFFI), taste appreciation (TSAI), and food–medicinal role (FMRI).

The second highest group ($500 > \text{CFSI} \geq 100$) included species such as *Allium cepa*, *Alpinia galanga*, *Curcuma angustifolia*, *Etlingera elatior*, and *Zingiber officinale* which are frequently consumed as vegetables, flavoring agents, or medicinal edibles. Their moderately high CFSI values reflect substantial cultural and culinary relevance, though they are less ubiquitous than the first group, often due to narrower distribution or less versatile edible parts.

Species with intermediate importance values ($100 > \text{CFSI} \geq 10$) were primarily consumed as snacks, seasonal vegetables, or for specific medicinal uses. Examples include *Amorphophallus paeoniifolius*, *Dioscorea esculenta*, and *Tacca leontopetaloides*, which serve complementary roles in local diets and traditional medicine.

The lowest CFSI group ($\text{CFSI} < 10$) consisted of species such as *Dioscorea alata*, *D. pseudotomentosa*, and *Smallanthus sonchifolius*, which were generally less preferred, collected from limited habitats, or consumed during periods of food scarcity. Interviews indicated that these species are mostly familiar to older community members and are rarely incorporated into contemporary meals.

The heat map analysis (Figure 6) illustrated pronounced variation in the component indices, revealing consistent clustering among species with high QI, AI, and FUI values, particularly within the genera *Allium*, *Alpinia*, and *Curcuma*. These species formed distinct high-use clusters, confirming their importance in local food traditions. In contrast, species such as *Dioscorea pseudotomentosa*, *D. alata* and *Smallanthus sonchifolius* clustered at lower values, reflecting restricted or occasional usage patterns.

Interestingly, several species with relatively high PUI and MFFI scores—such as *Allium ascalonicum*, *Colocasia esculenta* “Giant elephant ear”, *Kaempferia marginata*, and *Zingiber officinale*—demonstrated notable versatility, being consumed in multiple forms including fresh, cooked, powdered, or as herbal infusions. This flexibility likely explains their elevated CFSI values despite moderate availability scores.

Species with low FMRI values generally exhibited weak associations with medicinal uses, which contributed to their overall lower CFSI scores despite being edible. However, some taxa—such as *Daucus carota* subsp. *sativus* and *Nelumbo nucifera*—showed balanced scores across several indices, underscoring their dual role in local dietary practices and folk remedies.

Overall, the integration of these ethnobotanical indices within the CFSI framework provides a comprehensive view of culturally significant edible plants in Pa Tio District. The findings highlight the importance of a small group of multifunctional species while also documenting the diverse yet variable roles of many lesser-used taxa. These insights

offer valuable guidance for future research, conservation planning, and the promotion of culturally important food resources in Northeastern Thailand.

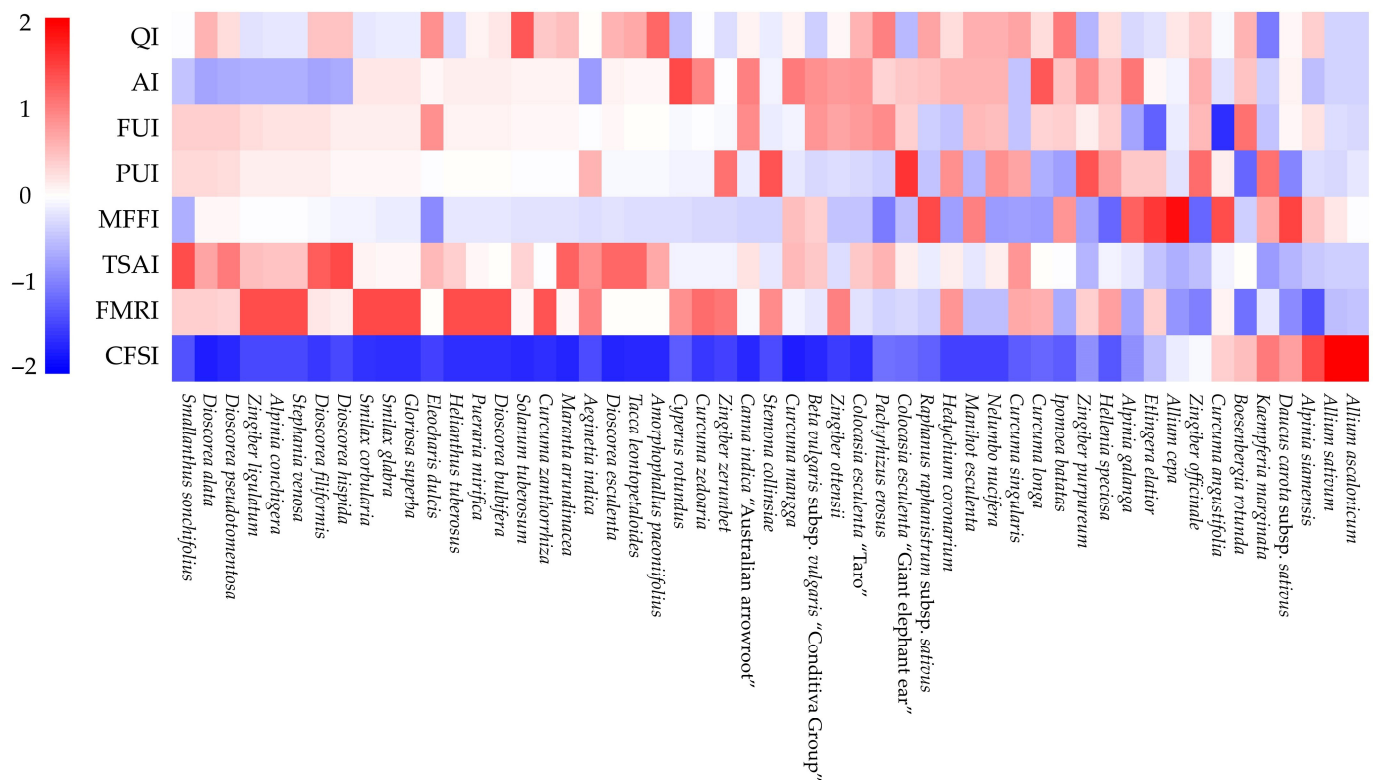


Figure 6. Heatmap of EUO plants in Maha Sarakham Province, Thailand.

3.4. Ethnomedicinal of EUO Plants

3.4.1. Condition of Plants Used and Routes of Administration of EUO Plants Used as Medicine

Among the medicinal EUO plants recorded, fresh materials were used more frequently, accounting for 68.52% of all preparations, while 31.48% were based on dried materials (Table S2).

Regarding routes of administration, oral use was the most common, representing 83.33% of all reported applications. Dermal application accounted for 12.96%, whereas topical administration was the least common at 3.70% (Table S2).

3.4.2. Preparation Methods

The medicinal use of underground plant parts in Maha Sarakham Province involves diverse and well-defined preparation practices (Table S2). Decoction represents the predominant method, particularly for species such as *Aeginetia indica*, *Curcuma singularis*, *Cyperus rotundus*, *Etilingera elatior*, *Gloriosa superba*, *Hellenia speciosa*, *Smilax glabra*, and *Stephania venosa*. These preparations generally require boiling fresh or dried rhizomes or tubers and consuming the strained liquid, often with specified dosages that reflect long-standing community knowledge.

Fresh rhizomes of several Zingiberaceae species are commonly pounded or pressed to extract juice for treating gastrointestinal problems and inflammatory conditions. For example, *Curcuma longa* is processed into fresh juice for oral use, while its dried rhizomes are powdered for topical application. Likewise, *Zingiber ottensii* and *Z. zerumbet* are prepared as pounded pastes, sometimes combined with salt or lime water for external treatment of sprains or swelling.

Multiple processing methods are associated with certain taxa. *Curcuma zanthorrhiza* and *C. zedoaria* may be administered as decoctions or liquor-based preparations. *Zingiber purpureum* is notable for its complex polyherbal formulations incorporating peppers, clove, and borneol, prepared as either hot-water infusions or compressed herbal pills. Tonic species such as *Pueraria mirifica* and *Smilax corbularia* are typically sun-dried, ground into powder, and formed into boluses.

Some species require minimal preparation; *Helianthus tuberosus*, for instance, is consumed fresh. Others, such as *Stemona collinsiae*, involve more specialized techniques for oral or topical use.

3.4.3. Fidelity Level (%FL) of EUO Plants Usad as Medicine

The Fidelity Level (FL, %) was calculated to assess the degree of consensus among informants regarding the medicinal uses of edible EUO plants (Table S2). FL represents the proportion of informants who cite a particular species for its primary therapeutic application, providing insight into the cultural significance and perceived effectiveness of each plant.

Several species exhibited high FL values (>70%), indicating strong agreement among informants on their specific medicinal applications. *Gloriosa superba* tubers recorded the highest FL (83.3%) for musculoskeletal disorders, particularly for relieving knee pain and rheumatism. Similarly, *Zingiber zerumbet* rhizomes showed an FL of 80% for gastrointestinal disorders, including bloating and abdominal discomfort. *Etlingera elatior* rhizomes were highly cited for dermatological conditions (FL = 80%), demonstrating widespread recognition of their topical efficacy.

Species with moderate FL values (40–70%) reflect a somewhat lower consensus, often due to multiple therapeutic uses or local variation in traditional knowledge. For example, *Curcuma longa* rhizomes had FL values of 60% for gastrointestinal issues and 40% for dermatological applications. *Kaempferia marginata* rhizomes exhibited FL values ranging from 20% to 46.7% across fever reduction, digestive, and respiratory uses. *Pueraria mirifica* tubers were reported for general tonic use, breast enhancement, and hair growth, with FL values of 56.25%, 31.25%, and 12.5%, respectively.

Lower FL values (<40%) were observed in species employed for multiple therapeutic purposes, where the consensus for any single use was diluted. For instance, *Zingiber purpureum* rhizomes had FL values of 60% for gastrointestinal disorders, 26.7% for respiratory ailments, and 13.3% for musculoskeletal conditions. This pattern indicates versatility in usage but less uniformity in informant agreement.

Overall, the FL analysis highlights that certain EUO species are highly recognized for specific medicinal uses, while others serve diverse therapeutic roles, reflecting the richness and complexity of ethnomedicinal knowledge in Maha Sarakham Province. A detailed summary of species used parts, preparation methods, therapeutic uses, and corresponding FL values is provided in Table S1.

3.4.4. Informant Consensus Factor (F_{ic}) of EUO Plants Used as Medicine

The Informant Consensus Factor (F_{ic}) was calculated to evaluate the level of agreement among informants regarding the medicinal uses of EUO plants across eight therapeutic categories (Table 4). F_{ic} values ranged from 0.722 to 1.000, indicating varying but generally strong levels of shared knowledge within the community.

The highest F_{ic} value (1.000) was observed for the cardiovascular system, reflecting complete agreement among informants, although this category was represented by only a single species and three use reports. High F_{ic} values were also recorded for general health (0.905) and obstetrics, gynaecology, and urinary disorders (0.900), suggesting con-

sistent and well-established traditional uses of EUO species for revitalization, postpartum care, and urinary-related conditions.

Table 4. Informant consensus factor (F_{ic}) of EUO species used as medicine in Maha Sarakham Province, Thailand.

Therapeutic Categories	Number of Use Report (N_{ur})	Number of Taxa (N_t)	F_{ic}
Cardiovascular System	3	1	1.000
General Health	22	3	0.905
Obstetrics, Gynaecology and Urinary Disorders	41	5	0.900
Musculoskeletal and Joint Diseases	54	8	0.868
Gastrointestinal Disorder	105	15	0.865
Infection, Parasite and Immune System	39	7	0.842
Integumentary System	26	6	0.800
Respiratory System	19	6	0.722

The categories with the greatest number of use reports, including musculoskeletal and joint diseases ($N_{ur} = 54$; $F_{ic} = 0.868$) and gastrointestinal disorders ($N_{ur} = 105$; $F_{ic} = 0.865$), also showed high consensus. These findings highlight the importance of EUO plants in alleviating common ailments such as muscle pain, inflammation, digestive discomfort, and abdominal disorders within the local ethnomedicinal system.

Moderate but still substantial consensus was found in infection, parasite, and immune-related conditions ($F_{ic} = 0.842$) and the integumentary system ($F_{ic} = 0.800$), indicating that EUO species are also recognized for their antimicrobial, antiparasitic, and dermatological applications. The respiratory system had the lowest consensus ($F_{ic} = 0.722$), with six taxa reported for 19 use reports, suggesting a broader diversity of species employed for cough, colds, and respiratory discomfort, and consequently lower agreement on specific taxa.

3.5. Economic Value of EUO Plants

The trade of EUO plants in local markets represents an important source of supplementary income for local vendors. A total of 26 EUO taxa were recorded as being sold (Figure 7 and Table 5), covering a range of plant parts including tubers, corms, rhizomes, bulbs, pseudostems, and taproots. Market prices varied considerably among species, from 10 to 390 THB/kg, depending on plant part, quality, seasonal availability, and consumer preference.



Figure 7. Examples of EUO plants found for sale in local markets: (A) *Allium cepa* L.; (B) *Allium sativum* L.; (C) *Alpinia siamensis* K.Schum.; (D) *Boesenbergia rotunda* (L.) Mansf.; (E) *Daucus carota* subsp. *sativus* (Hoffm.) Schübl. & G.Martens; (F) *Raphanus raphanistrum* subsp. *sativus* (L.) Schmalh.; (G) *Solanum tuberosum* L.; (H) *Zingiber officinale* Roscoe (photographs by Tammanoon Jitpromma).

Table 5. Economic value of EUO plants traded in local markets, including scientific name, price (THB/kg), monthly sales volume (kg), availability (Months/Year), and estimated average yearly income per trader (THB/a Trader) (EV).

Scientific Name	Price (THB/kg) *		Monthly Sales Volume (kg)	Availability (Months/Year)	EV
	Min	Max			
<i>Smallanthus sonchifolius</i> (Poepp.) H. Rob.	230	390	20.3	6	37,758.00
<i>Helianthus tuberosus</i> L.	100	120	12.5	12	16,500.00
<i>Boesenbergia rotunda</i> (L.) Mansf.	40	50	30.5	12	16,470.00
<i>Allium sativum</i> L.	65	90	17.3	12	16,089.00
<i>Curcuma mangga</i> Valetton & Zijp	70	80	15.3	12	13,770.00
<i>Curcuma longa</i> L.	40	60	20.5	12	12,300.00
<i>Allium ascalonicum</i> L.	65	110	10.6	12	11,130.00
<i>Zingiber officinale</i> Roscoe	30	50	20.1	12	9648.00
<i>Beta vulgaris</i> subsp. <i>vulgaris</i> “Conditiva Group”	50	60	14.6	12	9636.00
<i>Curcuma zanthorrhiza</i> Roxb.	50	80	11	12	8580.00
<i>Dioscorea hispida</i> Dennst.	70	90	20	5	8000.00
<i>Nelumbo nucifera</i> Gaertn.	50	80	15.2	8	7904.00
<i>Amorphophallus paeoniifolius</i> (Dennst.) Nicolson	50	70	10.8	12	7776.00
<i>Raphanus raphanistrum</i> subsp. <i>sativus</i> (L.) Schmalh.	25	30	23.5	12	7755.00
<i>Alpinia siamensis</i> K. Schum.	25	40	19.4	12	7566.00
<i>Curcuma singularis</i> Gagnep.	50	80	28.3	4	7358.00
<i>Solanum tuberosum</i> L.	40	45	14.2	12	7242.00
<i>Pachyrhizus erosus</i> (L.) Urb.	10	20	37.2	12	6696.00
<i>Colocasia esculenta</i> (L.) Schott “Taro”	20	30	21.2	12	6360.00
<i>Alpinia galanga</i> (L.) Willd.	25	40	15.2	12	5928.00
<i>Daucus carota</i> subsp. <i>sativus</i> (Hoffm.) Schübl. & G. Martens	18	25	18.2	12	4695.60
<i>Eleocharis dulcis</i> (Burm.f.) Trin. ex Hensch.	45	50	16	6	4560.00
<i>Allium cepa</i> L.	20	40	11.5	12	4140.00
<i>Curcuma angustifolia</i> Roxb.	30	50	25.1	4	4016.00
<i>Ipomoea batatas</i> (L.) Lam.	10	20	21.6	12	3888.00
<i>Aeginetia indica</i> L.	80	100	5.2	4	1872.00

* Exchange rate—1 USD = 32.39 THB (as of 22 November 2025).

Table 5 presents the economic characteristics of the traded taxa. Those with higher market prices and broad availability generally produced greater estimated yearly incomes (EV) for traders. *Smallanthus sonchifolius* exhibited the highest EV (37,758 THB/year), followed by *Helianthus tuberosus*, *Boesenbergia rotunda*, and *Allium sativum*, both of which showed stable monthly sales and year-round availability. Notably, the extended selling periods of several species—particularly *Allium cepa*, *Curcuma longa*, and *Solanum tuberosum*—do not strictly reflect their natural phenology. Instead, vendors rely on post-harvest storage, allowing these products to remain available throughout the year despite their limited natural harvest seasons.

These patterns highlight that EUO plants contribute meaningfully to local market economies, offering both continuous and seasonal income opportunities. While a few high-value species dominate annual earnings, many others supplement household income through consistent or periodic trade.

4. Discussion

4.1. Ethnobotanical and Ecological Significance of EUO Plants

The diversity of EUO plants in Maha Sarakham Province reflects complex interactions among ecological availability, cultural preference, and historical cultivation practices. The dominance of Dioscoreaceae, Amaryllidaceae, and Zingiberaceae is consistent with other Asian ethnobotanical studies, where these families are valued for their multi-purpose rhizomes and tubers [42,43]. Beyond nutritional value, their widespread cultivation suggests a long-term coevolutionary relationship between humans and these plants, in which selection pressures favored species with palatable, storable, and medicinally active underground organs [44].

The presence of both native and introduced taxa (58.5% vs. 41.5%) underscores dynamic cultural and agroecological processes in the region [45]. None of the recorded species in this study are invasive. Introduced taxa may fill dietary or medicinal niches not covered by native species, reflecting adaptive strategies for food security under environmental and socio-economic constraints [46]. Their integration into local food systems demonstrates that introduced species can be valuable cultural and nutritional resources without posing ecological risks associated with invasive species.

In addition to native and introduced taxa, one species recorded in this study—*Dioscorea pseudotomentosa*—is endemic to Thailand. The presence and continued use of an endemic species in local food systems highlights its cultural significance and the community's reliance on region-specific plant resources. The traditional knowledge associated with its harvesting and utilization may also contribute to its in situ conservation, as locally embedded cultural practices often promote sustainable use of narrowly distributed taxa. However, the restricted geographic range of endemic species underscores the need for careful monitoring and conservation planning, particularly as habitat alteration, land-use change, and modernization may increase pressure on wild populations.

Meanwhile, wild-harvested native species continue to highlight the importance of natural ecosystems as reservoirs of agrobiodiversity, with implications for both conservation and resilience against market or climate pressures [47].

Importantly, the harvesting of underground organs often requires uprooting the entire plant. Consequently, intensive or unregulated collection from wild populations can threaten the persistence of native EUO species, potentially leading to local population declines or even extinction [48]. This raises conservation concerns, particularly for species with limited distribution or slow regeneration rates [49]. Sustainable harvesting practices, including rotational collection, partial harvest, and promotion of cultivation, are therefore essential to balance ethnobotanical use, food security, and biodiversity conservation [50].

4.2. Multifunctionality, Cultural Embeddedness, and Dietary Resilience

The multifunctionality of EUO plants—serving as staple foods, condiments, snacks, beverages, and medicinal resources—demonstrates their integration into a holistic food system in which nourishment and healing are closely intertwined. This multifunctionality enhances dietary resilience by providing diverse macronutrients, micronutrients, and bioactive compounds within a single plant group, reducing reliance on external food sources and supporting household nutrition throughout the year [51]. EUO species are particularly important for food security because their underground organs remain protected in the soil, allowing them to withstand drought, flooding, and other climatic disturbances that commonly affect aboveground crops. Their storability, both in situ and after harvest, provides dependable calorie and nutrient sources during periods of scarcity, aligning with climate-smart agriculture strategies aimed at strengthening community resilience [52].

From an agricultural perspective, many EUO plants are low-input, hardy species that adapt well to marginal soils and variable environmental conditions. Their compatibility with mixed-cropping, agroforestry, and home-garden systems offers opportunities for sustainable agricultural diversification [53]. Encouraging smallholder farmers to cultivate EUO species can reduce the risks associated with monoculture dependence, enhance soil health, and increase the ecological stability of local farming systems [54]. At the same time, several species possess strong market potential, and the development of value-added products—such as dried rhizomes, herbal drinks, and medicinal extracts—could expand rural income opportunities and support community-based enterprises [55].

The cultural embeddedness of EUO plants further reinforces their importance. High CFSI values for species such as *Allium ascalonicum* and *Boesenbergia rotunda* indicate that food preference, culinary tradition, and intergenerational knowledge transmission sustain their continued use and cultivation [56]. As keystone cultural plants, EUO species shape dietary identity and strengthen social cohesion through shared preparation practices and ritual uses. This socio-cultural foundation helps maintain agricultural engagement with these species even amid modernization and crop commercialization [57].

Altogether, EUO plants contribute significantly to food security, agricultural sustainability, and cultural continuity. Strengthening support for their cultivation through local extension programs, community seed systems, and improved market access could enhance both livelihood resilience and biodiversity conservation in the region [58].

4.3. Ethnomedicinal Knowledge and Public Health Implications

High FL and F_{ic} values for certain species indicate both specificity and consensus in traditional medicine. This pattern suggests selective retention of knowledge for plants with reliable pharmacological efficacy, reflecting a “cultural pharmacopoeia” shaped by centuries of empirical use [59]. Moreover, the integration of medicinal functions into daily diets reduces dependence on formal healthcare and supports preventative health strategies, particularly in rural communities with limited access to medical infrastructure [60].

Species with lower FL but multiple uses, such as *Zingiber purpureum*, reflect flexible therapeutic strategies, indicating that ethnomedicinal knowledge balances specificity with redundancy to ensure coverage of multiple ailments. This mirrors patterns in other ethnobotanical contexts, where redundancy and polypharmacy enhance community resilience to disease variability [61].

A notable finding in the current study is that two medicinal EUO species—*Cyperus rotundus* and *Hellenia speciosa*—were observed by the authors to appear in palm-leaf manuscripts from the region, demonstrating continuity of traditional knowledge from historical records to contemporary practice. However, many other taxa in these manuscripts remain ambiguous due to archaic language and uncertain identification, and numerous manuscripts, though well-preserved, remain underutilized because of the lack of systematic botanical interpretation [62,63]. This highlights the need for collaborative research involving ethnobotanists, local healers, and manuscript specialists to study and validate these historical records. Integrating ethnobotanical field data with careful taxonomic verification of the manuscripts could provide valuable insights into the continuity of traditional knowledge, clarify historical plant uses, and guide the conservation and sustainable utilization of EUO species in Maha Sarakham Province [64].

4.4. Conservation Implications and Sustainable Management

EUO plants play an important role in household food security in Maha Sarakham Province. Their underground storage organs provide dependable sources of carbohydrates and micronutrients, and they can be kept for long periods without refrigeration. These characteristics make them particularly valuable during times of seasonal scarcity or irregular rainfall, a pattern also noted in studies of other underutilized crops in tropical regions [52]. Because tubers and rhizomes persist below ground, many EUO species can survive drought conditions better than annual vegetables, offering a measure of stability as climatic variability increases [65].

Although several EUO species are traditionally cultivated, the present study found that many tuber- and rhizome-forming plants still produce relatively low yields when grown under local conditions. In some cases, such as certain *Dioscorea* and *Zingiberaceae* taxa, the harvested organs remain small or inconsistent in size even after careful cultivation. As a result, local production is often insufficient to meet household demand. This shortfall encourages continued reliance on wild populations, especially in community forests and fallow fields. Because harvesting underground organs typically requires removing the entire plant, excessive collection from the wild may put pressure on natural populations and, over time, increase the risk of local depletion. These observations point to the need for future work on domestication, propagation trials, and improved cultivation practices tailored specifically to EUO species. Strengthening local access to quality planting materials, improving soil and water management practices, and encouraging smallholder experimentation through homegarden trials would help increase overall productivity. Such efforts, combined with community-based conservation of wild stands, would allow EUO plants to contribute more effectively to local food systems while reducing pressure on natural populations [66,67].

4.5. Economic Value and Sustainable Livelihoods

The availability patterns of EUO plants in local markets reveal a complex interplay between plant biology, storage potential, and cultivation constraints. Several species are sold continuously throughout the year despite having distinct natural harvest periods. This year-round availability is largely attributable to the intrinsic durability of their underground organs, which can be stored for extended periods without significant quality loss. Bulbs, rhizomes, and certain tubers—such as those of *Allium*, *Curcuma*, and *Solanum* species—are particularly amenable to long-term storage. Vendors therefore rely on post-harvest storage to maintain a stable market supply, mitigating seasonal shortages and ensuring consistent income. These storage-tolerant species consequently exhibit higher market reliability and play a key role in sustaining household economies [68].

In contrast, a subset of EUO species appears in markets only during specific periods of the year. These seasonal species depend heavily on wild harvesting because they are difficult to cultivate, have narrow ecological requirements, or produce low yields under managed conditions. For example, certain *Dioscoreaceae* and *Zingiberaceae* species remain largely reliant on natural populations due to their long maturation times, unpredictable productivity, or sensitivity to soil and microhabitat conditions [69]. The limited ability to cultivate these taxa not only restricts their market presence but also increases extraction pressure on wild stands, raising concerns about long-term sustainability and potential population decline if unmanaged harvesting continues [70].

These contrasting availability patterns underscore the need for targeted research to strengthen future production systems. Studies focusing on propagation methods, phenological responses under cultivation, and improved soil and water management could enhance yields and reduce dependence on wild sources. Developing community-based cultivation models and evaluating the feasibility of small-scale domestication trials would

further support local livelihoods while safeguarding natural resources. Ultimately, improving the cultivation and management of both seasonal and year-round EUO species will be critical for ensuring economic stability, promoting resource sustainability, and reducing pressure on forest ecosystems.

4.6. Research Gaps and Future Directions

This study provides an extensive overview of EUO plant diversity, uses, and market roles in Maha Sarakham Province; however, several areas require further investigation to strengthen sustainable management and utilization. Many EUO species, particularly those harvested exclusively from the wild, remain poorly understood in terms of growth behavior, regeneration capacity, and ecological requirements. Detailed ecological and phenological studies are necessary to determine which taxa can be sustainably harvested and which hold potential for small-scale or commercial cultivation.

Economic aspects also warrant deeper analysis. Although this study highlights meaningful income contributions from EUO plants, the broader value chain—including trader networks, storage and transport practices, seasonal price variability, and consumer demand—remains insufficiently documented. Understanding these components would help identify opportunities for improving market efficiency, reducing post-harvest losses, and enhancing household income security.

Taxonomic uncertainties persist for several low-frequency species recorded during fieldwork, particularly those whose vernacular names appear in palm-leaf manuscripts. Because these manuscripts were written in an archaic regional language and employ terminology no longer commonly used, many plant references remain ambiguous. Addressing these uncertainties requires collaborative work among ethnobotanists, palm-leaf manuscript specialists, and local healers, combining field-based observations with historical textual analysis. Such interdisciplinary study would help clarify species identities, verify boundaries, and ensure accurate documentation of culturally significant EUO taxa.

Future research should also examine how environmental and social changes—such as climate variability, declining fallow land, and shifting cultural practices—affect EUO availability and knowledge transmission. Long-term monitoring across multiple districts in Maha Sarakham Province would provide insight into population trends and local adaptation strategies.

Finally, integrating research findings into community-based programs and provincial development plans is essential. Clear guidelines for sustainable harvesting, improved propagation techniques, and value-added processing could support both biodiversity conservation and livelihood enhancement. Strengthening collaboration among researchers, local communities, and agricultural agencies will be key to promoting the long-term sustainability of EUO resources and their contribution to regional food security.

5. Conclusions

This study documented 53 EUO taxa from 22 families in Maha Sarakham Province, highlighting their multifaceted contributions to local diets, medicine, culture, and livelihoods. The results demonstrate that EUO plants are integral to both managed and natural food sources, with most species being cultivated while some continue to be collected from the wild. Rhizomes and tubers were the most commonly used parts, often prepared in diverse ways to provide nutrition, flavor, and health benefits. Certain species, such as *Allium ascalonicum* L., *Gloriosa superba* L., and *Smallanthus sonchifolius* (Poepp.) H. Rob., stood out for their high cultural, medicinal, and economic value, reflecting their importance in local markets, household income, and traditional healthcare practices. Ethnomedicinal knowledge remains strong, particularly for gastrointestinal, musculoskeletal, and general health

treatments, highlighting the integration of food and medicine in local diets. The findings emphasize that EUO plants support food security, dietary resilience, agricultural sustainability, and cultural continuity. Sustainable harvesting, domestication, and improved cultivation practices, combined with the preservation and transmission of traditional knowledge, are essential to safeguard these plants. Strengthening local propagation, market access, and community-based conservation efforts will enhance both ecological, economic, and cultural benefits, ensuring that EUO resources continue to contribute to rural livelihoods and regional food system resilience.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/d17120846/s1>, Table S1: Cultural Food Significance Index (CFSI) evaluation of EUO Plants in Maha Sarakham Province; Table S2: Ethnomedicinal of edible underground storage organ (USO) plants in Maha Sarakham Province, including scientific name, fidelity level (FL), used parts, condition of plants used (CoP), preparation method, route of administration (RoA), application, and therapeutic categories.

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Appendix A

Semi-Structured interview form for EUO plants.

Semi-Structured Interview Form for EUO Plants in Maha Sarakham Province

A. Informant Information

1. Name / Initials: _____ (optional)
2. Age: _____ years
3. Gender: ☐ Male ☐ Female ☐ Other
4. Ethnicity: _____
5. Language: _____
6. Religion: _____

B. Plant Information

1. Local/vernacular name of the plant: _____
2. Scientific name (if known): _____
3. Family (if known): _____
4. Is the plant wild-harvested or cultivated? ☐ Wild ☐ Cultivated ☐ Both

C. Plant Uses

1. Which part(s) of the plant are used? (Check all that apply)
 - ☐ Root / Tuber
 - ☐ Rhizome
 - ☐ Corm
 - ☐ Leaf
 - ☐ Stem
 - ☐ Flower / Inflorescence
 - ☐ Fruit / Seed
 - ☐ Other: _____
2. What is the main use of the plant?
 - ☐ Food / Culinary ☐ Medicinal ☐ Ritual / Religious ☐ Other: _____
3. Please describe preparation and processing methods for each used part: _____

4. Are there specific dishes, remedies, or rituals associated with this plant?

5. How frequently is the plant used?

☐ Daily ☐ Weekly ☐ Seasonally ☐ Rarely

6. Are there any cultural or symbolic meanings attached to this plant?

D. Economic Importance

1. Is this plant sold or traded locally? ☐ Yes ☐ No
2. If yes, what is its typical price or value? _____
3. Are there specific local markets or sellers where it is available?

E. Additional Notes / Observations

Figure A1. Semi-Structured interview form for EUO plants in Maha Sarakham Province.

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