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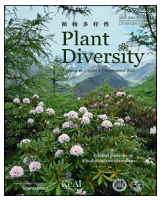

Review article

A review of ethnobotanical studies reveals over 500 medicinal plants in Mindanao, Philippines

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ABSTRACT

Medicinal plants have long been used to treat various diseases in both indigenous and non-indigenous populations of Mindanao, Philippines. Here, we extracted data from ethnobotanical studies to compile a comprehensive list of these medicinal plants and identify how and for what purpose they are most commonly used. We identified 530 verified medicinal plant species across 372 genera in 118 families. The two most frequently cited species were *Euphorbia hirta* and *Psidium guajava*. The most represented family was Fabaceae and the most represented genus was *Ficus*. A total of 28 medicinal plant species are designated as threatened at the national or global level; of these, 11 are endemic to the Philippines. Medicinal plant preparations most commonly use leaves for oral administration to treat various diseases such as digestive issues, including diarrhea. This study underscores the need for further ethnobotanical investigations, particularly in areas lacking records. It also emphasizes the need for conservation of threatened and endemic medicinal plants to ensure sustainable utilization of this valuable resource.

1. Introduction

Plants provide important resources for humans, including food, timber, and textiles. Plants have also been utilized since the earliest civilizations to cure various illnesses (Petrovska, 2012). In some regions (e.g., Africa, Asia, and Latin America), plants are the source of herbal medicines that treat illnesses for an estimated 85% of the human population (Jamshidi-Kia et al., 2018). For example, traditional medical practitioners in Nigeria treat malaria with *Mangifera indica*, *Enantia chlorantha*, *Alstonia boonei*, and *Cymbopogon citratus* (Evbuomwan et al., 2023). In rural communities in India, cuts and wounds are treated with *Curcuma longa* and *Ocimum tenuiflorum* (Gogoi and Sen, 2023). The Buyi communities in Yunnan, China medicate rheumatism with *Paederia scandens* and *Sargentodoxa cuneata* (Xiong et al., 2020). Cashinahua herbalists in the Peruvian Amazon reportedly utilize *Pseuderanthemum congestum* to treat herpes, snake bites, and cataracts (Horackova et al., 2023). Indeed, the vital role of plants as sources of medicines has been recognized by various scientific disciplines, including pharmacy and natural products chemistry (Gurib-Fakim, 2006).

The Philippines is considered one of the most biodiverse hotspots in the world (Myers et al., 2000). Home to 1.9% of the endemic plants around the globe, the Philippines has 10,078 species of vascular plants belonging to 1962 genera across 287 families (Pelser et al., 2011 onwards; https://www.philippineplants.org). Many of these plants are used to treat various diseases, as demonstrated in ethnobotanical documentation around the country. For instance, the *Kalanguya* tribe in Tinoc, Ifugao has been shown to use 125 plant species to treat illnesses such as stomachache, cough and colds, and sore eyes (Balangcod and Balangcod, 2011). In addition, communities in Talacogon, Agusan del Sur are known to use 25 plant species to treat diarrhea (Arquion, 2016). More recently, a study has reported that the indigenous *Panay Bukidnon* in Lambunao, Iloilo use a total of 131 medicinal species to address 91 diseases (Cordero et al., 2022a). The Philippines Department of Health (DOH) has released a list of scientifically validated medicinal plants that includes *Allium sativum*, *Blumea balsamifera*, *Cassia alata* (syn. of *Senna alata*), *Clinopodium douglasii* (syn. of *Micromeria douglasii*), *Ehretia microphylla*, *Momordica charantia*, *Peperomia pellucida*, *Psidium guajava*, *Quisqualis indica* (syn. of *Combretum indicum*), and *Vitex negundo* (Boy et al., 2018).

The use of medicinal plants in the Philippines can be traced back to the precolonial period (Zaide and Zaide, 2013). The earliest records of medicinal plants in the country were documented during

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the Spanish regime by missionaries, such as Father Francisco Ignacio Alcina in 1669, Father Pablo Clain in 1712, and Father Juan Delgado from 1751 to 1754 (Bantug, 1953). In the 19th century, Trinidad H. Pardo de Tavera (1892) published his book *Plantas Medicinales de Filipinas*, which described the medicinal properties of 214 plant species (Bantug, 1953). Even during the American occupation, scholars remained keen on this area of study. Two significant publications during this time were William H. Brown's (1921) *Official Philippine Medicinal Plants* and Leon Maria Guerrero's (1921) *Medicinal Uses of Philippine Plants*. Further, during the post-colonial era, Eduardo Quisumbing (1951) published his work titled *Medicinal Plants of the Philippines*. This valuable document contained information about the medicinal importance of 858 floral species (Bantug, 1953). In 1974, the National Integrated Research Program on Medicinal Plants (NIRPROMP) was formed to document plants used by over a thousand folk healers in the Philippines (Eusebio and Umali, 2004; World Intellectual Property Organization, 2013; United Nations Development Programme [UNDP], 2023). The results have eventually been translated to various medicinal plant formulations, such as *Vitex negundo* tablet and syrup for asthma and cough, *Blumea balsamifera* tablet for urolithiasis, and *Senna alata* lotion for cutaneous fungal infections (Maramba-Lazarte, 2020).

In recent years, ethnobotanical surveys have documented the use of medicinal plants in various indigenous groups in the country, including the *Ayta* (Ragragio et al., 2013; Tantengco et al., 2018) and *Kalanguya* (Balangcod and Balangcod, 2011) tribes in Luzon, the *Ati* tribe (Ong and Kim, 2014; Cordero et al., 2020, 2022b; Cordero and Alejandro, 2021) in Visayas, and the *Manobo* tribe (Dapar et al., 2020a, 2020b, 2020c, 2020d; Paraguison et al., 2020; Cabugatan et al., 2022; Ilagan et al., 2022) in Mindanao. Medicinal plants have also been inventoried based on the knowledge of other groups, such as herbalists (Caunca and Balinado, 2021), traditional healers (Miano et al., 2011; Del Fierro and Nolasco, 2013; Fiscal, 2017; Rubio and Naive, 2018; Fabie-Agapin, 2020), vendors (Barcelo et al., 2022) and the locals (Arquion, 2016; Calangi et al., 2019; Belgica et al., 2021; Omac et al., 2021; Docot et al., 2022). Although several empirical studies have been published, synthesis of this body of knowledge in the country remains scarce. Recent reviews have focused on medicinal plants used by Filipinos for anemia prevention and treatment, gynecologic care, and obstetric care (Magtalas et al., 2023a, 2023b, 2023c). Lim et al. (2022) stated that performing a literature review would be valuable as it may synthesize the current state of knowledge in the field and identify noteworthy gaps that could inform further research.

Mindanao, a major island group in the Philippines, is home to several human populations: Muslim Filipinos, Indigenous Peoples (IPs) (locally known as *Lumads*), and the Christian majority (Abubakar, 2019). Historically, Muslim Filipinos and Indigenous Peoples were the islands' original inhabitants, with Christian settlers arriving during the American regime (Abubakar, 2019). The largest ethnic groups are the *Bisaya*, *Cebuano*, and *Ilonggo*, respectively (Philippine Statistics Authority [PSA], 2023a). Mindanao harbors rich floral diversity (see Amoroso et al., 2012; Polizon and Amoroso, 2014; Lillo et al., 2019; Coritico et al., 2020; Medecilo-Guiang et al., 2021). However, many species on the island group are threatened (see Aribal and Buot, 2009; Lumista et al., 2016; Coritico et al., 2022). Previous reports have noted that both indigenous and non-indigenous people on Mindanao rely on locally available plants to address various health issues (e.g., Gruyal et al., 2014; Pizon et al., 2016; Pucot and Demayo, 2021; Palero et al., 2023). Even so, a comprehensive list of medicinal plant species that these people use or know has yet to be made available. Only a compilation of plant species used specifically for treating cancer or tumors by selected groups has been published (Pucot et al., 2019).

In this review, we collate data from ethnobotanical fieldwork on medicinal plants of Mindanao, Philippines. Specifically, we sought to determine the (1) patterns, trends, and profiles of ethnobotanical studies in the region; (2) diversity and conservation status of identified medicinal plants; (3) commonly used plant parts and modes of preparation and administration; and (4) disease categories treated with documented plant species. Similar to other scholars (e.g., De Boer and Cotingting, 2014; Phumthum et al., 2018), we argue that the compilation arising from this review may inform further drug discovery not just locally but also globally, particularly in regions with shared plant resources. Additionally, it might contribute valuable data to the global database of medicinally valuable plant species.

2. Methods

2.1. Study area

Mindanao, the second-largest group of islands in the southern Philippines, spans 97,530 km^2, accounting for approximately 33% of the country's total land area of 300,000 km^2. Positioned between latitudes 04° to 11°N and longitudes 118° to 127°E, it is bordered by the Bohol Sea to the north, the Philippine Sea to the east, the Celebes Sea to the south, and the Sulu Sea to the west. Its complex topography ranges from the lowlands of Agusan and Cotabato provinces to the summit of Mt. Apo National Park at 2954 m above sea level, the highest point in the entire country. According to the modified Coronas climate classification (Coronas, 1920; Kintanar, 1984), Mindanao experiences a varied climate. Most provinces exhibit a Type IV climate, characterized by a relatively uniform distribution of rainfall throughout the year. Conversely, certain areas, particularly the northeastern part, feature a Type II climate, with no dry season and very pronounced maximum rainfall from December to February. Meanwhile, other parts, such as most of the Zamboanga Peninsula, have a Type III climate, where seasonal variations are less pronounced, and a relatively dry period persists for one to three months. These topographic and climatic variations have certainly shaped Mindanao's ecological features with its rich and diverse vegetation. For example, Lillo et al. (2019) documented a staggering 432 native plant species within the various forest habitats of Dinagat Island. Among these are the country's endemic species, such as *Greeniopsis euphlebia* Merr. and *Nepenthes truncata* Macfarl. Similarly, Zapanta et al. (2019) conducted a survey among disturbed habitats within the Mt. Apo Natural Park, revealing 136 tree species, including endemic and threatened species, such as *Cinnamomum mercadoi* S.Vidal.

Comprising six regions, 28 provinces, 33 cities, 422 municipalities, and 10,087 villages Mindanao serves as home to over 26 million Filipinos (PSA, 2023b). The majority (≈ 70%) are non-indigenous Christian settlers (Abubakar, 2019). Despite being a minority, about 60% (UNDP, 2013) of the country's total population of Indigenous People (9.84 million people as of 2020) reside in Mindanao (PSA, 2023a). Notably, certain groups in the region, like the *Sama* and *Yakan* tribes of Isabela City, Basilan, are identified as both Muslim tribes and indigenous (PSA, 2023a), reflecting the intricate cultural mosaic of the area.

2.2. Study selection

This study systematically searched for extant literature on ethnobotanical surveys of medicinal plants in Mindanao,

Philippines. In doing so, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA] 2020 Statement (Page et al., 2021) was followed. Database searches were conducted in Scopus and Web of Science on 2 August 2023. The search terms, including the Boolean operators and truncations, utilized in the identification of studies via databases are shown in Table S1. The titles from the two databases were then compared, and duplicates were removed. Citation (forward and backward) searching and manual searching via Google Scholar were also done on 3 August 2023. A two-stage screening process (review of titles and abstracts, and full-text assessment) was employed. This study only included papers that present ethnobotanical fieldwork conducted in Mindanao, Philippines, and are published in English or Filipino in peer-reviewed journals or conference proceedings. Reviews, errata, and inaccessible documents were excluded from this study. Ethnobotanical studies with incomplete or unspecified data were also excluded. All three authors independently performed the screening of each identified record. Disagreements were then resolved through discussion. The PRISMA flow diagram (Fig. 1) shows the result of the search process.

2.3. Data extraction and classification

All included studies were profiled. The following data were extracted from each of the included studies: title, author(s), publication year, study area(s), data collection method(s), sampling technique(s), survey date, participants, ethnobotanical index used, plant species, plant part(s) used, and modes of preparation and administration. Extracted data on modes of preparation and administration were classified according to the categories presented by Alamgir (2017) and Fakchich and Elachouri (2021), respectively.

2.4. Taxonomic validation

The scientific names declared in this review were validated and updated to reflect the latest accepted names per World Flora Online [WFO] (2023a; http://www.worldfloraonline.org). Only accepted botanical names were included and reported in this review. Those scientific names marked as synonyms were merged with their accepted names. For example, the synonyms *Citrus decumana* L. and *Sansevieria trifasciata* Prain were merged with their accepted names, *Citrus maxima* (Burm.) Merr. and *Dracaena trifasciata* (Prain) Mabb., respectively. Names marked as unchecked, such as *Artemisia coarctata* Forselles and *Citrofortunella microcarpa* (Bunge) Wijnands, were excluded. Unspecified scientific names, such *Agave* sp. and *Ficus* sp., were also excluded. Family names were verified with the Angiosperm Phylogeny Website, version 14 (Stevens, 2017). Verification of both scientific names and family names was done on 27 August 2023.

2.5. Conservation status

This study used the IUCN Red List of Threatened Species Version 2022-2 (2023; https://www.iucnredlist.org) to determine species conservation status. It also utilized the Department of Environment and Natural Resources Administrative Order No. 2017-11 [DAO 2017-11] (DENR, 2017) to identify threatened plant species at the national level.

2.6. Classification of diseases

We standardized data on classification of diseases by adopting the International Classification of Primary Care, 2nd edition (ICPC-2), a WHO-accepted classification system. The ICPC was used because its categorization system is patient-informed and closer to ethnomedical reality (Staub et al., 2015).

2.7. Data analysis

This study employed descriptive statistics, mainly frequency, and percentage, to quantitatively analyze extracted data. We also used ethnobotanical indices, such as relative frequency of citation (RFC) and informant consensus factor (ICF). RFC was obtained by using the following formula: RFC = FC/N, where FC is the frequency of citation or the number of informants that mentioned the use of species, and N is the total number of informants (Tardio and Pardo-de-Santayana, 2008). In this review, each study included was treated as a single informant. ICF, on the other hand, was calculated using the following formula: $ICF = (n_{ur} - n_t)/(n_{ur} - 1)$, where n_{ur} is the number of use-reports for each disease category and n_t is the number of species used (Heinrich et al., 1998). To determine use-reports, this study adopted the methodology of Abe and Ohtani (2013). A single-use report was recorded when a study cited a

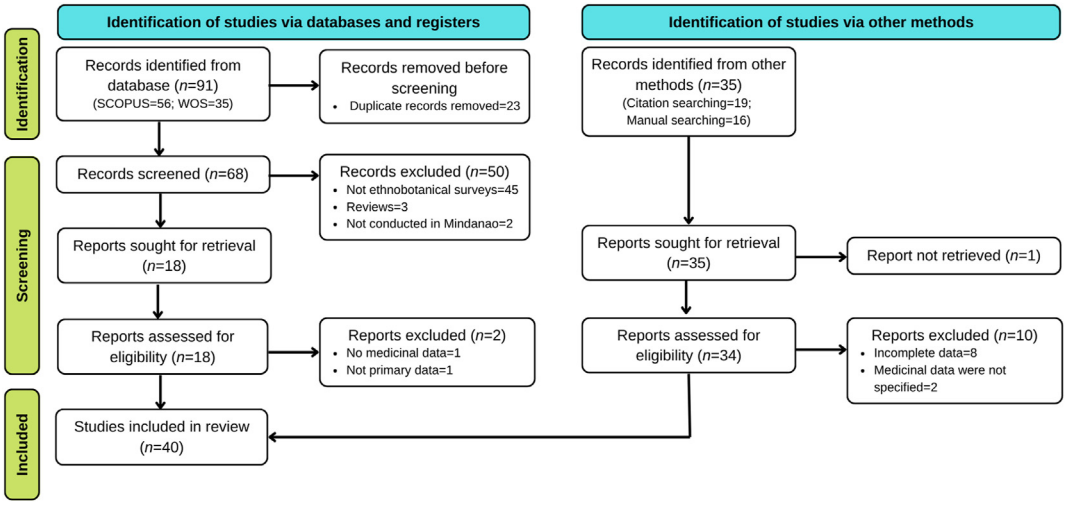

Fig. 1. PRISMA flow diagram of the study selection process.

species for a specific disease or mentioned a species used for multiple diseases within the same category. Conversely, multiple-use reports were noted when at least two studies cited a species for the same disease or when a study cited a species being used for diseases across different categories.

3. Results

Our initial search identified a total of 126 studies on medicinal plants of Mindanao, Philippines. Of these, 91 were from the Scopus and Web of Science databases, whereas 35 were obtained through citation searching and manual searching via Google Scholar. After the removal of duplicates and review of titles and abstracts, 53 studies were retrieved and assessed for eligibility. Full-text assessment revealed that only 40 studies met the criteria for inclusion in this review. Section 2.2 presents the selection criteria employed, while Table 1 shows the summary of included studies.

3.1. Ethnobotanical studies on Mindanao

The geographical distribution of ethnobotanical studies in Mindanao, Philippines, is shown in Fig. 2. Results revealed that ethnobotanical documentation was done in 16 of the 28 Mindanao provinces. Among them, Zamboanga del Sur had the highest number, with nine studies. This was followed by Agusan del Sur and Surigao del Sur with seven and six publications, respectively. Bukidnon and South Cotabato had three studies each, while Agusan del Norte, Lanao del Norte, Misamis Occidental, North Cotabato, Zamboanga del Norte, and Zamboanga Sibugay had two studies each. Further, each of the provinces of Basilan, Davao del Sur, Davao Occidental, Lanao del Sur, and Surigao del Norte had one published paper.

Over the years, there has been a gradual accumulation of ethnobotanical studies in Mindanao, with the majority (n = 26, 65.0%) being published in the last five years, 2019 to 2023. The oldest identified record included in this review was of Yen and Gutierrez (1974). We found no studies conducted between 1975 and 2011. The number of publications peaked in 2020 at 10 (25.0%). Fig. 3 shows the temporal trend of ethnobotanical publications in Mindanao, Philippines.

All included studies were published in English. The majority were journal articles (n = 38, 95.0%), while the remainder were conference papers. Most studies (n = 26, 65.0%) surveyed certain tribes in Mindanao, while other studies collected data from non-indigenous groups. Informants of each of the included studies ranged from 3 to 335 individuals. They were primarily recruited through purposive (n = 13, 32.5%) or snowball (n = 15, 37.5%) sampling. Eighteen studies (45%) did not state the sampling technique employed, while five studies (12.5%) did not disclose their sample sizes.

The most utilized method of data collection was interview (n = 38, 95.0%). This was followed by using questionnaires (n = 21, 52.5%) and holding discussions (n = 14, 35.0%). Other methods included group conversation and participatory rural appraisal. In terms of analysis, only 15 studies (37.5%) used indices to quantify ethnobotanical data. Relative frequency of citation and use value were the most utilized indices, with eight studies using each of them. Five studies employed family importance value, fidelity level, and informant consensus factor indices. Other ethnobotanical indices used were the cultural importance index, relative frequency, use diversity, and use-report.

3.2. Medicinal plant families, genera and species and their conservation status

This review found that all included studies documented a total of 661 species with medicinal uses. Verification and updating in the WFO excluded those unlisted and unchecked species. Unspecified species were also excluded, while synonyms were merged with their accepted names. As a result, a total of 530 verified and updated medicinal plant species are reported in this review. They belong to 372 genera in 118 families. Table S2 presents the list of medicinal plants in Mindanao, Philippines.

Among all plant families reported, Fabaceae was the most represented with 37 species (Fig. 4a). This was followed by Asteraceae (32 species), Lamiaceae (29 species), Moraceae (24 species), and Malvaceae (23 species), respectively. The number of species representing other families ranged from 1 to 19 species. Further, the most represented genera were *Ficus* of Moraceae (20 species), *Allium* of Amaryllidaceae (8 species), *Phyllanthus* of Phyllanthaceae (6 species), *Solanum* of Solanaceae (7 species), and *Piper* of Piperaceae (6 species) (Fig. 4b). Other genera were represented by 1–4 species.

Table 2 shows the 15 most cited species in ethnobotanical studies of Mindanao. *Euphorbia hirta* L. topped the list with 26 mentions. *Psidium guajava* L. followed this with 25 mentions. *Blumea balsamifera* (L.) DC. and *Vitex negundo* came next with 24 mentions each. Following them were *Cymbopogon citratus* (DC.) Stapf, *Eleusine indica* Gaertn., *Jatropha curcas* L., *Mimosa pudica* L., and *Tinospora crispa* (L.) Hook.f. & Thomson with 23 mentions each, and *Annona muricata* L., *Artemisia vulgaris* L., *Carica papaya* L., *Persea americana* Mill., *Plectranthus scutellarioides* R.Br., and *Kalanchoe pinnata* (Lam.) Pers. with 21 mentions each.

Further, this review reveals that 28 medicinal plant species belonging to 21 families found in Mindanao are threatened at the global or national level (Table 3). Of these species, 17 are listed in the IUCN Red List (2023), while 18 are in DAO 2017-11 (DENR, 2017). At the global level, one species is categorized as critically endangered, eight are endangered, and another eight are vulnerable. At the national level, two species are critically endangered, nine are endangered, five are vulnerable, and two are categorized as other threatened species. They accounted for 5.28% of the 530 species included in this review. Additionally, 11 out of 28 threatened species are classified as endemic to the Philippines (DENR, 2017).

3.3. Plant parts used and modes of preparation and administration

This review reveals that in Mindanao either the whole or parts of medicinal plants are used to treat various diseases. Even so, the leaf of the majority of species (n = 356, 67.2%) is the most commonly used part (Fig. 5a). This is followed by the root (184 species, 34.7%), bark (92 species, 17.4%), stem (90 species, 17.0%), and fruit (67 species, 12.6%). Following the classification of Alamgir (2017), the modes of preparation were categorized as dry, external, and internal. Records show that internal preparation is the most preferred for many species (n = 416, 78.5%) (Fig. 5b). This is followed by external (293 species, 55.3%) and dry (15 species, 2.83%) preparations. The mode of administration followed the classification used by Fakchich and Elachouri (2021). As shown (Fig. 5c), preparations from 408 species (77.0%) are administered orally. A total of 301 species (56.8%) are administered externally. Only five species (0.94%) were reported to be administered in other ways, such as gargling and inhalation.

Table 1
Profile of the included studies.

Study Code	Author(s) and year	Study Area (i.e., province/s)	Data collection method[a]	Sampling technique[b]	Date of survey	Informants	Sample size	Ethnobotanical index used[c]	No. of plant species
S1	Yen and Gutierrez (1974)	South Cotabato	I	Not stated	July–December 2023	*Tasaday*	Not stated	None	2[d]
S2	Olowa et al. (2012)	Lanao del Norte	I, Q	Not stated	January–March 2012	*Higaonon*	65	None	62
S3	Gruyal et al. (2014)	Surigao del Sur	I, Q	Ps	March–October 2013	Residents	50	None	65
S4	Morilla et al. (2014)	Zamboanga del Sur	D, I, Q	Ss	April–May 2013	*Subanen*	27	None	60
S5	Olowa and Demayo (2015)	Lanao del Norte	I, Q	Not stated	January–May 2014	*Muslim-Maranao*	228	None	122
S6	Arquion (2016)	Agusan del Sur	I	Ps	November 2014 –March 2015	Local dwellers and herbalists	50	None	25
S7	Aya-ay (2016)	Davao del Sur	I	Not stated	August 2003	Community members	Not stated	None	71
S8	Cabanting and Perez (2016)	North Cotabato, Zamboanga del Norte, Zamboanga del Sur	I	Ss	2014–2015	Not stated	27	None	1
S9	Pizon et al. (2016)	Zamboanga del Sur	D, I	Not stated	Not stated	*Subanen*	7	None	89
S10	Dapar and Demayo (2017)	Agusan del Sur	I	Ss	Not stated	*Manobo*, traditional healers, and residents	9	None	1
S11	Malawani et al. (2017)	Lanao del Sur	D, I	Not stated	Not stated	*Maranao*	90	None	68
S12	Odchimar et al. (2017)	Bukidnon	I	Not stated	Not stated	*Talaandig*	Not stated	None	66
S13	Cruz et al. (2018)	Surigao del Sur	I, Q	Not stated	mid–2017	*Manobo*	4	None	19
S14	Rubio and Naive (2018)	North Cotabato	D, I, Q	Ps	Not stated	Traditional healers	20	None	63
S15	Alduhisa and Demayo (2019)	Misamis Occidental	I, Q	Not stated	November 2013 –March 2014	*Subanen*	83	None	113
S16	Campilan et al. (2019)	South Cotabato	D, I, Q	Not stated	July 10, 2014	*T'boli*	7	RFC, UV	28
S17	Morilla and Demayo (2019)	Zamboanga del Sur	D, I, Q	Ps	Not stated	Traditional practitioners	6	RF	42
S18	Dapar et al. (2020a)	Agusan del Sur	D, I	Ps, Ss	March 2018–April 2019	*Manobo* and *Higaonon*	145	FIV, RFC	43
S19	Dapar et al. (2020b)	Agusan del Sur	D, I	Ps, Ss	March 2018–May 2019	*Manobo*	335	CI, FL, ICF, UD, UR, UV	122
S20	Dapar et al. (2020c)	Agusan del Sur	D, I, Q	Ps, Ss	October 2018 –February 2019	*Manobo*	50	FIV, RFC	48
S21	Dapar et al. (2020d)	Agusan del Sur	D, I	Ps, Ss	March 2018 –April 2019	*Manobo*	95	FIV, RFC	90
S22	de Guzman et al. (2020)	Zamboanga Sibugay	I, Q	Ss	Not stated	*Visayan*	31	None	50
S23	Fabie-Agapin (2020)	Zamboanga del Sur	Q	Ss	December 2018 –February 2019	Traditional healers	11	None	71
S24	Molina et al. (2020)	Zamboanga del Sur	I	Ps	Not stated	Traditional healers	3	None	16
S25	Olandag (2020)	Misamis Occidental	I, Q	Not stated	Not stated	*Subanen*	Not stated	None	60
S26	Paraguison et al. (2020)	Agusan del Sur	D, I	Ps, Ss	November 2019	*Manobo*	144	FIV, RFC	40
S27	Peneciba (2020)	Surigao del Sur	D, I	Ps	Not stated	Traditional healers	15	None	45
S28	Gruyal et al. (2021)	Surigao del Sur	I, Q	Not stated	September –October 2020	Residents	50	ICF	35
S29	Madjos and Ramos (2021a)	Basilan, Zamboanga del Norte, Zamboanga del Sur, Zamboanga Sibugay	I, Q	Ss	Not stated	*Bajau*, *Chavacano*, *Sama*, *Subanen*, *Subanon*, *Tausug*, *Visayan*, and *Yakan*	330	None	208
S30	Madjos and Ramos (2021b)	Zamboanga del Sur	I	Ss	June–October 2019	*Bajau*	30	FL, ICF, UR, UV	36
S31	Montero and Geducos (2021)	Surigao del Sur	I, Q	Not stated	December 2019 –January 2020	Local folks	30	None	46
S32	Naive et al. (2021)	Bukidnon	D, I, Q	Ss	August 2018–March 2019	*Talaandig*	19	UV	97
S33	Nuñeza et al. (2021)	Agusan del Norte, Surigao del Norte	I, Q, GC	Not stated	July 11 – November 15, 2019	*Mamanwa*	143	None	78
S34	Omac et al. (2021)	Agusan del Norte	Q, PRA	Not stated	Not stated	Local communities	120	RFC	125
S35	Pucot and Demayo (2021)	Zamboanga del Sur	I, Q	Ps, Ss	August 2020–March 2021	Traditional healers, masseur/masseuse, community members	23	None	56
S36	Alinsug et al. (2022)	South Cotabato	D, I	Not stated	Not stated	*B'laan*	30	FL, ICF, UV	101

(*continued on next page*)

Table 1 (*continued*)

Study Code	Author(s) and year	Study Area (i.e., province/s)	Data collection method[a]	Sampling technique[b]	Date of survey	Informants	Sample size	Ethnobotanical index used[c]	No. of plant species
S37	Cabugatan et al. (2022)	Davao Occidental	I, Q	Ps	Not stated	*Manobo*	30	RFC, UV	41
S38	Dapar and Amoroso (2022)	Bukidnon	I	Not stated	Not stated	*Tigwahon-Manobo*	Not stated	None	23
S39	Ilagan et al. (2022)	Surigao del Sur	I	Not stated	Not stated	*Manobo* and *Mamanwa*	127	FIV, FL, ICF, UV	48
S40	Palero et al. (2023)	Agusan del Norte	I	Ss	January –March 2022	Traditional healers	40	FL, RFC, UV	34

Note. The studies included herein are arranged chronologically, then alphabetically according to the first author's surname.
[a] Data collection method – D: discussion, GC: group conversation, I: interview, PRA: participatory rural appraisal, Q: questionnaire.
[b] Sampling technique – Ps: purposive sampling, Ss: snowball sampling.
[c] Ethnobotanical index used – CI: cultural importance index/value, FIV: family importance value, FL: fidelity level, ICF: informant consensus factor, RF: relative frequency, RFC: relative frequency of citation, UD: use diversity, UR: use-report, UV: use value.
[d] Number of medicinal species reported.

3.4. Disease categories and informant consensus factor

Table 4 presents the number of use-reports, number of species used, and ICFs for various disease categories. This study reveals that use-reports ranged from 5 to 764, with ear diseases having the fewest and digestive diseases the most. Similarly, the ear disease category had the lowest number of species ($n = 5$), while the digestive disease category had the highest ($n = 279$). Further, ICFs ranged from 0 to 0.636. Among all categories, the digestive disease category had the highest ICF. Other categories that had ICFs of at least 0.500 included general and unspecified diseases (0.587), respiratory diseases (0.582), skin diseases (0.579), and endocrine/metabolic and nutritional diseases (0.503). On the other hand, the ear disease category had only five use-reports and five species used. Hence, it yielded an ICF of 0, the lowest among all disease categories.

4. Discussion

4.1. Ethnobotanical studies on Mindanao

In this study, we reviewed ethnobotanical surveys conducted in Mindanao, Philippines. We collated data on medicinal plants known or used by the indigenous and non-indigenous groups in the region. Ethnobotanical fieldwork in Mindanao has been geographically concentrated, given that only three provinces had more than five publications while the rest had none to three. This could be due to the limited number of researchers and institutions working on this topic, which would skew their efforts to a few areas. As such, more studies should be conducted, especially in provinces that remain un(der)studied, such as Davao Oriental, Davao del Norte, Sulu, and Tawi–Tawi, among others. Nonetheless, the field has definitely gained interest, as demonstrated by the number of publications post-2010. Before 2010, only one study was published (Yen and Gutierrez, 1974). This study accounted for plants deemed useful by *Tasadays* of South Cotabato, including two medicinal plants. The increase in ethnobotanical documentation in recent years has also been observed in other parts of the world, such as Morocco (Fakchich and Elachouri, 2021), Nepal (Poudel et al., 2022), and Southwest China (Liu et al., 2016), possibly due to the growing interest of the scientific community in this topic (Fakchich and Elachouri, 2021).

Many of the studies included in our review inventoried the ethnobotanical knowledge of several indigenous and ethnolinguistic groups, including the *Bajau*, *B'laan*, *Chavacano*, *Higaonon*, *Mamanwa*, *Manobo*, *Maranao*, *Muslim-Maranao*, *Sama*, *Subanen*, *Subanon*, *Talaandig*, *Tasaday*, *Tausug*, *T'boli*, *Tigwahon-Manobo*, *Visayan*, and *Yakan*. Other studies collected data from residents, traditional healers/practitioners, herbalists, masseurs/masseuses, and other community members. Despite the number of ethnobotanical investigations, knowledge of medicinal plants of most tribes in Mindanao remains undocumented. Dapar and Alejandro (2020) found that only 36% of the indigenous populations in this island group had been surveyed. Further profiling revealed that a certain proportion of studies did not specify their sampling technique nor sample size. The lack of this crucial information hinders a thorough grasp of the study and its alignment with existing literature and hampers the ability to make a sound assessment regarding the generalizability of the study's findings and conclusions (Turner, 2020). This review also found that many studies employed multiple data collection methods, of which, interviews were the most utilized. This may be because doing interviews, especially semi-structured ones, efficiently captures extensive information from many individuals in a short time while keeping the interviewees at ease to answer questions (Albuquerque et al., 2006). In addition,

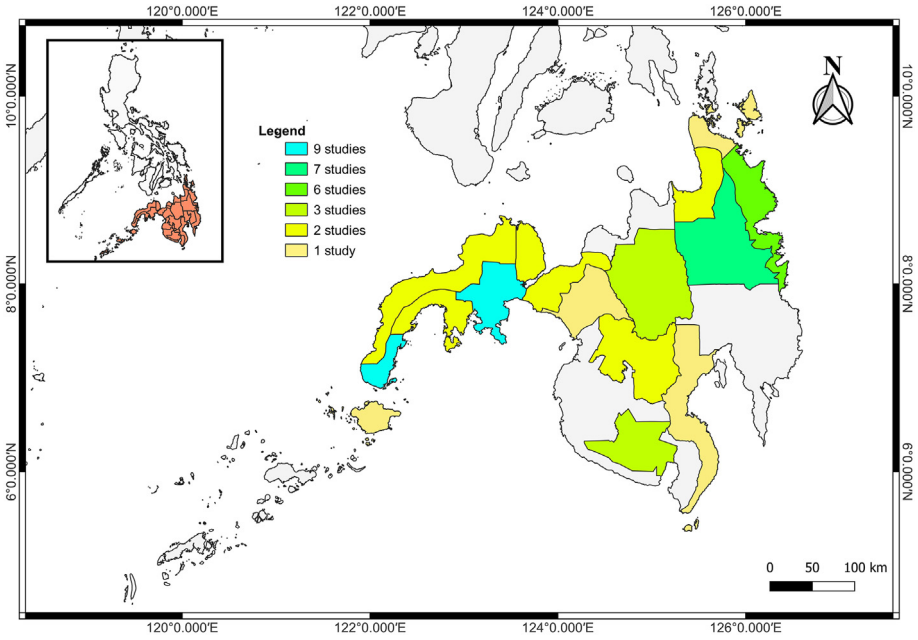

Fig. 2. Spatial distribution of ethnobotanical studies in Mindanao, Philippines.

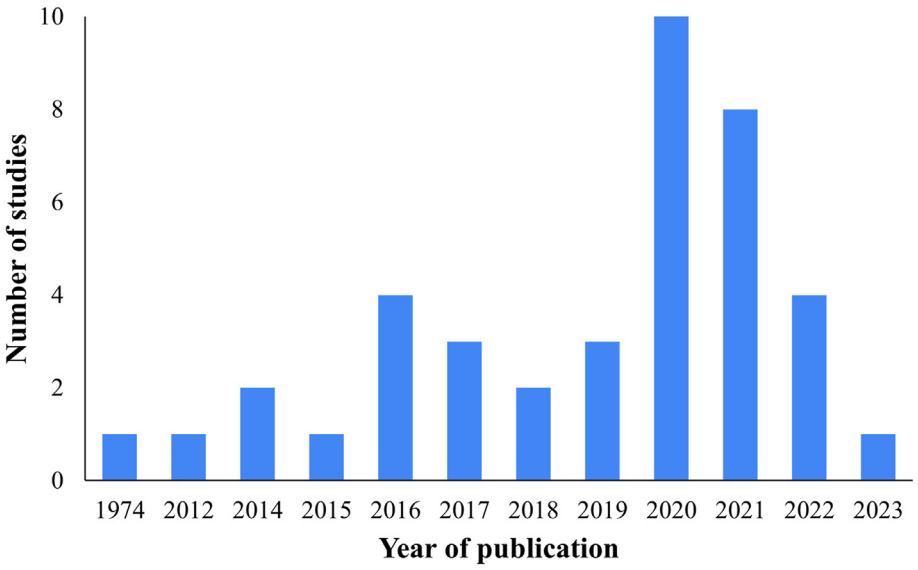

Fig. 3. Number of ethnobotanical publications on Mindanao (1974–2023).

ethnobotanical indices have only been employed in recent studies, affirming the conclusion of Medeiros et al. (2011) that ethnobotanists are increasingly using quantitative indices.

4.2. Medicinal plant families, genera and species and their conservation status

This comprehensive review has identified and documented 530 verified and updated medicinal plant species belonging to 372 genera across 118 families. This figure constitutes 5% of the total flora in the country (Pelser et al., 2011 onwards). This proportion aligns with the global average, where about 5% of the estimated 391,000 plant species worldwide have been shown to have medicinal uses (Royal Botanic Gardens Kew, 2016). The number of medicinal plant species reported in this review is relatively higher than those documented in diverse regions worldwide, e.g., Barak Valley, India (216 species; Barbhuiya et al., 2022), and Sarawak, Malaysia (166 species; Abu Bakar et al., 2023).

Among the medicinal plant families occurring in Mindanao, Fabaceae, and Asteraceae were the two most represented. This could be due to a high number of species that belong to these families. In fact, they are two of the largest plant families not just in the country but also worldwide. In the Philippines, they were represented by at least 379 and 158 species, respectively (Pelser

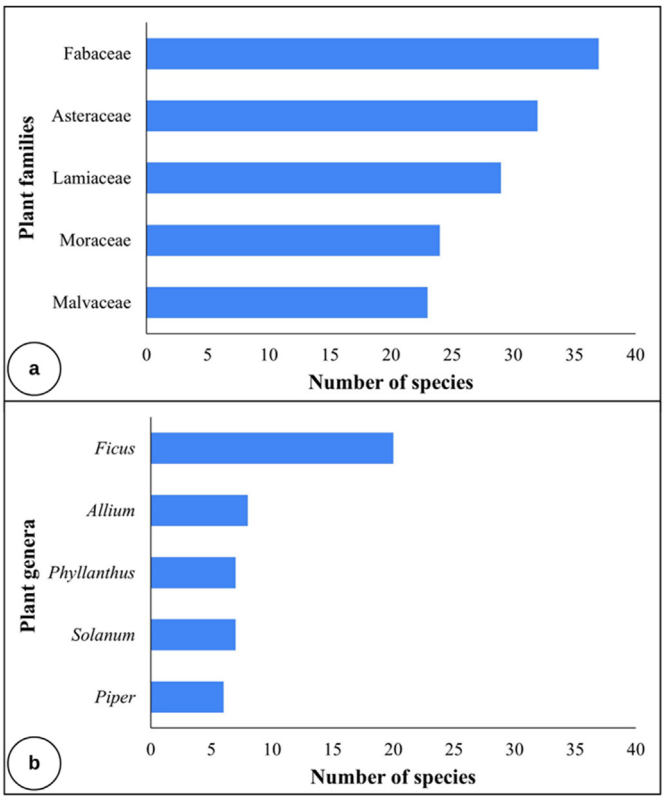

Fig. 4. Most represented families (a) and genera (b) of medicinal plants in Mindanao, Philippines.

et al., 2011 onwards). Worldwide, they have approximately 19,500 and 24,700 species, respectively (Christenhusz and Byng, 2016). Previous research has indicated that plant families that have high species richness have more useful species (Palchetti et al., 2023). Previous reviews also revealed that these two plant families registered a high number of medicinal plant species (Fakchich and Elachouri, 2021; Palchetti et al., 2023). Further, we found that *Ficus* was the most represented genus. With at least 101 species known to occur in the country, it is one of the largest genera (Pelser et al., 2011 onwards). *Ficus* species are known to have antioxidant properties (Sirisha et al., 2010). For example, *Ficus elastica* Roxb. ex Hornem., which was reportedly used against cancer (Fabie-Agapin, 2020; Madjos and Ramos, 2021a), was found to contain compounds with potent anti-proliferative activity (Mbosso Teinkela et al., 2016).

The most frequently cited species used for medicinal purposes was *Euphorbia hirta*. Belonging to family Euphorbiaceae, this herb grows in various parts of the world, especially in tropical and subtropical regions (WFO, 2023b). Several studies included in this review (e.g., Olowa et al., 2012; Dapar et al., 2020b; Cabugatan et al., 2022) reported that decoction of the whole of this plant or its part(s) can be used against dengue fever. Experimental evidence has even shown that *E. hirta* contains compounds with antiviral activity against the dengue virus (Tayone et al., 2014). Despite this, further investigations have been recommended to establish its potential and validate its clinical utility (Mir et al., 2012; Perera et al., 2018), given that adverse effects have also been reported in the literature (see Capule, 2013). In addition, *E. hirta*, which was reportedly used against tumors (Madjos and Ramos, 2021a), was found to contain kaemferol, a bioactive compound displaying anti-breast cancer activity (Widyananda et al., 2023).

Interestingly, among the ten scientifically validated medicinal plants in the country, only three were mentioned in the majority of the studies. These are *Psidium guajava*, *Blumea balsamifera* and *Vitex negundo*. These species have been approved for use in treating tooth decay and gum infection, cough, and urinary stones, respectively (Zarsuelo et al., 2018). Although further validation by the country's health authorities is required, global experimental evidence indicates that other important species also show potential biological activities. For example, *Cymbopogon citratus*, reportedly used against cancer (Omac et al., 2021), showed that its extract has significant antiproliferative properties, particularly against liver cancer (Rahhal et al., 2024). Rahhal et al. (2024) also revealed that *C. citratus* extract contains phytoconstituents like flavonoids and saponins, contributing to its antioxidant and anti-diabetic properties. Similarly, *Annona muricata*, reportedly used for diabetes (Madjos and Ramos, 2021a), is rich in polyphenols, making it potentially effective in managing diabetes mellitus and its complications (Justino et al., 2018). Furthermore, *Jatropha curcas*, known to manage wounds (Dapar et al., 2020c; Naive et al., 2021), contains alkaloids, flavonoids, glycosides, saponins, steroids, and tannins in its stem extract, indicating its broad-spectrum antimicrobial potential (Igbinosa et al., 2009).

Having more than 500 species, Mindanao is indeed rich in medicinal plant resources. However, there exist various threats, such as agricultural development and expansion, deforestation, and mining (Agduma et al., 2023). Even in a protected area like Mt. Apo Natural Park, destruction of certain habitats has been noted and is imminent in some areas due to agriculture and settlements (Zapanta et al.,

Table 2
Most cited medicinal plant species in Mindanao, Philippines.

Rank	Species	Family	No. of citations	Relative frequency of citations
1	*Euphorbia hirta* L.	Euphorbiaceae	26	0.650
2	*Psidium guajava* L.	Myrtaceae	25	0.625
3	*Blumea balsamifera* (L.) DC.	Asteraceae	24	0.600
	Vitex negundo L.	Lamiaceae	24	0.600
4	*Cymbopogon citratus* (DC.) Stapf	Poaceae	23	0.575
	Eleusine indica Gaertn.	Poaceae	23	0.575
	Jatropha curcas L.	Euphorbiaceae	23	0.575
	Mimosa pudica L.	Fabaceae	23	0.575
	Tinospora crispa (L.) Hook.f. & Thomson	Menispermaceae	23	0.575
5	*Annona muricata* L.	Annonaceae	21	0.525
	Artemisia vulgaris L.	Asteraceae	21	0.525
	Carica papaya L.	Caricaceae	21	0.525
	Persea americana Mill.	Lauraceae	21	0.525
	Plectranthus scutellarioides R.Br.	Lamiaceae	21	0.525
	Kalanchoe pinnata (Lam.) Pers.	Crassulaceae	21	0.525

Note: There were 40 included studies that served as informants in this review.

Table 3
Threatened medicinal plant species of Mindanao, Philippines.

Family	Species	Status	
		IUCN[a]	DAO 2017-11[b]
Annonaceae	*Drepananthus apoensis* Elmer	VU	
Apocynaceae	*Voacanga megacarpa* Merr.	VU	
Araceae	*Alocasia zebrina* Schott ex Van Houtte*		VU
	Rhaphidophora korthalsii Schott*		OTS
Araucariaceae	*Agathis dammara* (Lamb.) Rich	VU	VU
Cardiopteridaceae	*Citronella mucronata* (Ruiz & Pav.) D. Don	VU	
Dipterocarpaceae	*Shorea astylosa* Foxw.*	EN	CR
	Shorea negrosensis Foxw.*		VU
Euphorbiaceae	*Jatropha mcvaughii* Dehgan & G.L. Webster	EN	
Fabaceae	*Afzelia rhomboidea* (Blanco) Fern.-Villi.	VU	EN
	Clianthus puniceus (G. Don) Sol. ex Lindl.	EN	
	Pterocarpus indicus Willd.	EN	VU
Lauraceae	*Cinnamomum mercadoi* S. Vidal*		OTS
Lycopodiaceae	*Huperzia squarrosa* (G. Forst.) Trevis		EN
Malvaceae	*Gossypium hirsutum* L.	VU	
Melastomataceae	*Medinilla surigaoensis* Regalado*		EN
Meliaceae	*Swietenia macrophylla* King in Hook.	VU	
Nepenthaceae	*Nepenthes saranganiensis* Sh. Kurata*		EN
	Nepenthes truncata Macfarl.*	EN	EN
Ophioglossaceae	*Ophioglossum pendulum* L.		EN
Orchidaceae	*Phalaenopsis amabilis* (L.) Blume		EN
	Phalaenopsis stuartiana Rchb.f.*		EN
Pandanaceae	*Pandanus mindanaensis* Martelli	EN	
Rubiaceae	*Coffea arabica* L.	EN	
	Greeniopsis euphlebia Merr.*	VU	CR
Thymelaeaceae	*Aquilaria malaccensis* Lam.	CR	EN
Urticaceae	*Dendrocnide venosa* (Elmer) Chew	EN	
Zingiberaceae	*Alpinia elegans* (C. Presl) K. Schum*		VU

Note: Species marked with an asterisk (*) are endemic to the Philippines (DENR, 2017).
[a] IUCN categories – CR: critically endangered, EN: endangered, VU: vulnerable.
[b] National categories – CR: critically endangered, EN: endangered, VU: vulnerable, OTS: other threatened species.

2019). All these may adversely impact this rich floral diversity. In fact, this review found that a few identified plants are already categorized as threatened at a global and country level. For instance, *Aquilaria malaccensis* Lam., known for cancer treatment (Omac et al., 2021) and addressing body pain, cough, and stomachache (Dapar and Amoroso, 2022), is critically endangered according to IUCN (2023) and endangered according to DENR (2017). In addition, the Philippine endemic trees *Greeniopsis euphlebia* Merr., cited for treating stomachache (Ilagan et al., 2022), and *Shorea astylosa* Foxw., for addressing physical relapse (Madjos and Ramos, 2021a), are both critically endangered according to DENR (2017). The IUCN (2023) classifies these plants as globally vulnerable and endangered, respectively. As such, it is essential to consider conservation strategies and resource management to ensure the sustainable utilization of these medicinal plant resources (Chen et al., 2016). Additionally, certain species listed in this review have been identified as non-native within the country, with some posing a threat as invasive species. Notable examples include *Chromolaena odorata* (L.) R.M. King & H. Rob., *Leucaena leucocephala* (Lam.) de Wit, and *Piper aduncum* L. (Department of Environment and Natural Resources-Biodiversity Management Bureau, 2020). These species are known for treating wounds (Madjos and Ramos, 2021a), managing parasitic worms (Fabie-Agapin, 2020), and remedying snake bites (Alinsug et al., 2022), respectively. Despite being medicinally valuable, these species need constant monitoring to prevent their spread and adverse impacts on native floral diversity.

4.3. Plant parts used and modes of preparation and administration

Of all plant parts, leaves are commonly utilized in preparing herbal remedies. The reliance on leaves may be due to its availability and accessibility compared to other parts (Cordero and Alejandro, 2021). Leaves can also be harvested more abundantly (Mbuni et al., 2020) and regenerate quickly, unlike other parts, such as roots and stems (Fabie-Agapin, 2020). The preferential use of leaves has also been practiced in other countries, e.g., China (Xiong et al., 2020), Turkey (Karaköse, 2022), and Nigeria (Evbuomwan et al., 2023).

Preparation of herbal remedies is a critical process as it determines how the medicinal properties of plants are released to best alleviate the intended ailment (Alamgir, 2017). This review reveals that most species are prepared for internal use. Examples of internal preparations include decoction, infusion, and ingestion. In fact, decoction has been the most preferred method among different groups in Mindanao (see Naive et al., 2021; Nuñeza et al., 2021; Alinsug et al., 2022; Cabugatan et al., 2022). We also found that the most common mode of administration for most species was oral. This mode of administration may be due to the method by which plants are prepared. Even so, Fakchich and Elachouri (2021) argued that both oral and external administration allow fast physiological action. The prominence of internal preparation and oral administration being reported in ethnobotanical studies may be because plant healing agents are more effective if taken internally (Alamgir, 2017).

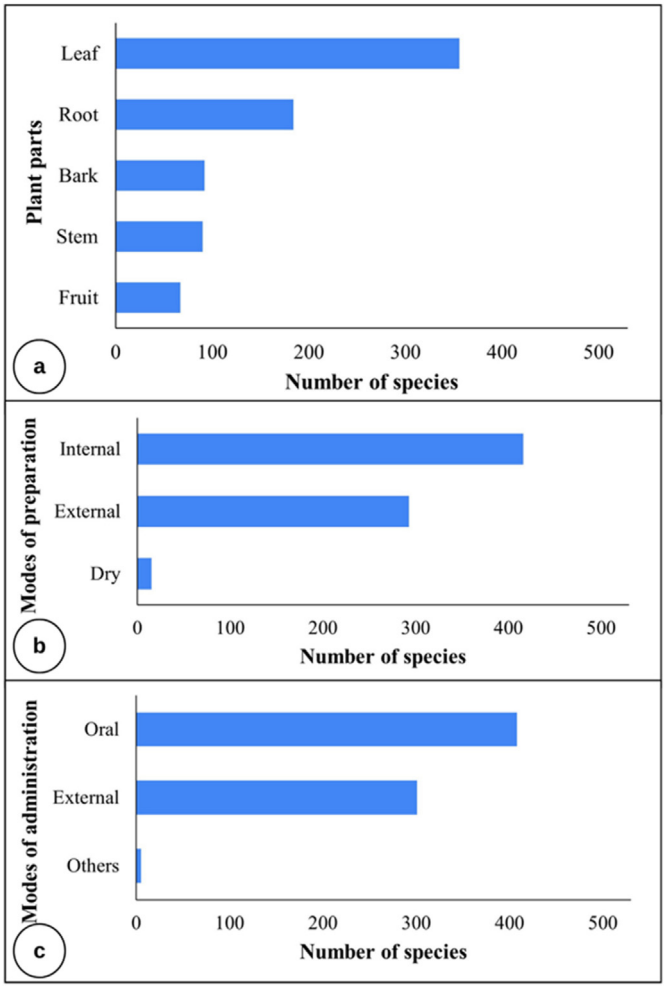

Fig. 5. Most common parts used (a), modes of preparation (b), and modes of administration (c) of medicinal plants in Mindanao, Philippines.

4.4. Disease categories and informant consensus factor

This review found that the highest number of use-reports among all disease categories was digestive disease. This finding suggests that many of the reviewed studies mentioned the use of various plant species in treating ailment(s) within this category (Amiguet et al., 2005). Further we found that the highest consensus reported in ethnobotanical studies of Mindanao was for plants used to treat digestive problems, despite documenting the greatest number of species used. A higher ICF indicates homogeneity of ethnobotanical information (Medeiros et al., 2011). It also means that a relatively large proportion of informants have reported a few species in addressing this disease category (Heinrich et al., 1998). A frequently identified digestive disease among studies is diarrhea, one of the leading causes of death not just in the Philippines (PSA, 2023c) but on a global scale as well (World Health Organization, 2020). Among the reported species, *Psidium guajava* was frequently cited as a treatment for diarrhea (Arquion, 2016; Dapar et al., 2020b; Omac et al., 2021). Various studies (e.g., Abbas et al., 2020; Ibeh et al., 2021; Charla et al., 2023) have demonstrated that *P. guajava* leaves contain bioactive compounds that have antidiarrheal potential. The use of *P. guajava* leaves against diarrhea has also been reported in other countries, such as French Polynesia (Chassagne et al., 2022) and Tanzania (Liheluka et al., 2023). The lowest ICF score was reported for ear diseases. This indicates that informants disagree on what species to use in the treatment of this ear diseases (Heinrich et al., 1998). Even so, ethnobotanical studies of indigenous groups in the Philippines has reported that the highest ICF is for ear diseases (e.g., Abe and Ohtani, 2013; Ong and Kim, 2014). As Caunca and Balinado (2021) argued, ICF values can differ across cultures, highlighting variations in the availability and utilization of medicinal plants unique to each region, as well as the specific health conditions for which these plants are used.

4.5. Limitations

This review provides an overview of ethnobotanical knowledge of medicinal plants in Mindanao, serving as a valuable resource for future researchers. However, the findings presented here should be approached with caution due to certain limitations. Firstly, the studies included were limited to journal articles and conference papers indexed in three databases (i.e., Google Scholar, Scopus, and Web of Science), potentially overlooking ethnobotanical data from other sources like gray literature. Future reviews could explore these additional sources to ensure a more comprehensive representation of ethnobotanical studies in the region. Secondly, although the scientific names of plants in this review have been verified and updated, they are solely based on the reported names in the included studies. Lastly, information on parts used, modes of

Table 4
Use reports and informant consensus factors for various disease categories.

Disease categories	Number of use reports	Number of species used	ICF
General and unspecified	672	278	0.587
Blood, blood forming organs, and immune mechanism	52	38	0.275
Digestive	764	279	0.636
Eye	27	21	0.231
Ear	5	5	0.000
Cardiovascular	183	94	0.489
Musculoskeletal	342	175	0.490
Neurological	151	106	0.300
Psychological	9	7	0.250
Respiratory	439	184	0.582
Skin	509	215	0.579
Endocrine/metabolic and nutritional	152	76	0.503
Urological	184	97	0.475
Pregnancy, childbearing, family planning	144	95	0.343
Female genital	74	52	0.301
Male genital	17	11	0.375

preparation and administration, and diseases treated rely on the data provided in the reviewed studies. Therefore, any inaccuracies in taxonomic identification or errors in reporting within these studies may impact the reliability of the data presented in this review.

5. Conclusion and future directions

This study presents data on medicinal plants known or used by both indigenous and non-indigenous populations in Mindanao, Philippines. Mostly published post-2010, 40 ethnobotanical studies conducted in 16 of its 28 provinces are included in this review. Data show that Mindanao has at least 530 medicinal plant species used to treat various diseases in 16 categories. These species belong to 372 genera of 118 families. Fabaceae is the most represented plant family, while *Ficus* is the most represented genus. The most cited species is *Euphorbia hirta*. Among all species, 28 are classified as threatened globally and nationally. The commonly used plant part for various herbal preparations is the leaf. The majority of the medicinal plants are prepared for internal use and are administered orally. Among the identified categories, digestive diseases exhibit the highest informant consensus factor, while ear diseases have the lowest.

It is hoped that this study will provide some guidance to future researchers conducting ethnobotanical fieldwork in the Philippines, especially in unexplored areas and among unstudied tribes. While this focuses on Mindanao, subsequent reviews may explore other island groups like Luzon and Visayas, contributing to a comprehensive understanding of Philippine ethnobotany. This review also underscores the importance of transparent reporting, emphasizing the need for future researchers to disclose sampling techniques and sample sizes for clearer interpretation of findings. Additionally, this study highlights the necessity of conducting phytochemical and pharmacological investigations on the most frequently cited plants, especially those not yet scientifically validated by the Philippines' Department of Health. Finally, it is recommended that similar studies be conducted every five or ten years to stay current with ethnobotanical research trends, identifying and addressing new gaps in knowledge.

CRediT authorship contribution statement

Joeime F. Meñiza: Conceptualization, Methodology, Investigation, Data curation, Writing - Original Draft. **Monica M. Pasco:** Conceptualization, Methodology, Investigation, Data curation, Writing - Original Draft. **Jemer A. Alimbon:** Conceptualization, Methodology, Investigation, Formal Analysis, Visualization, Writing - Original Draft, Writing - Review and Editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pld.2024.05.001.

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