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Short Communication: Biocultural patterns of medicinal plant use in the Gunung Sewu Karst of Central Java, Indonesia

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Abstract. *Wibowo CNP, Azizah CKG, Rizka DR, Maharani DS, Susatio R, Yasa A, Jumari, Saensouk S, Setyawan AD. 2025. Short Communication: Biocultural patterns of medicinal plant use in the Gunung Sewu Karst of Central Java, Indonesia. Intl J Trop Drylands 9: 181-191.* Karst landscapes represent environmentally constrained systems characterized by shallow soils, limited water availability, and strong seasonal variability, conditions that shape both ecological processes and human livelihoods. In such settings, traditional medicinal plant use constitutes an important biocultural adaptation that supports household health and resilience. Despite the ecological and cultural significance of karst regions, ethnobotanical studies integrating medicinal plant use with biocultural adaptation frameworks remain limited, particularly in the Gunung Sewu Karst of Central Java, Indonesia. This study aims to document medicinal plant diversity and to analyze patterns of plant use in relation to karst environmental constraints. Ethnobotanical data were collected through semi-structured interviews, field observations, and direct plant identification in two karst villages of the Gunung Sewu Karst Region. A descriptive analytical approach was applied to classify plant use, preparation methods, application routes, and treated ailments. A total of 25 medicinal plant species belonging to 16 families were recorded. Zingiberaceae was the most represented family, reflecting both ecological suitability and cultural familiarity. Medicinal plant use was dominated by herbaceous species, with leaves and rhizomes as the primary plant parts utilized. Decoction and oral administration were the most common preparation and application methods, while treated ailments mainly comprised mild to moderate conditions related to digestion, respiration, skin health, and musculoskeletal pain. The observed patterns indicate that ecological filtering, sustainable harvesting practices, and household-based healthcare strategies shape medicinal plant use in the Gunung Sewu Karst. By explicitly linking growth forms, harvested plant parts, and preparation methods to karst environmental constraints, this study demonstrates that traditional medicinal practices function as a coherent biocultural adaptation rather than isolated cultural remnants. These findings contribute to ethnobotanical research by highlighting the adaptive role of local knowledge systems in karst environments and underscore their relevance for community-based conservation and sustainable health strategies.

Keywords: Biocultural adaptation, ethnobotany, karst landscape, medicinal plants, traditional knowledge

INTRODUCTION

Karst landscapes are widely recognized as environmentally extreme systems characterized by shallow soils, high surface rock exposure, rapid subsurface water infiltration, and pronounced seasonal water scarcity. These conditions impose strong ecological constraints on vegetation growth, agricultural productivity, and the availability of natural resources for human communities (Ford and Williams 2007; Day 2010). In tropical regions, karst ecosystems support distinctive assemblages of flora and fauna adapted to drought stress, nutrient limitation, and heterogeneous microhabitats, resulting in high levels of ecological specialization (Goldscheider et al. 2020). Consequently, human livelihoods in karst areas are closely intertwined with environmental conditions, shaping unique land-use systems, subsistence strategies, and knowledge practices.

Within such constrained environments, biocultural knowledge emerges as an adaptive response to long-term interactions between humans and their surroundings. Traditional ecological knowledge, including plant use, management practices, and seasonal resource allocation, plays a critical role in maintaining household resilience under persistent environmental stress (Gadgil et al. 1993; Berkes 2012). In karst landscapes, where infrastructure development and access to biomedical services may be limited, communities often rely on locally available biological resources to meet subsistence and healthcare needs. This reliance promotes the retention and intergenerational transmission of plant-based knowledge that reflects both ecological availability

and culturally embedded preferences (Caillon et al. 2017; Toledo et al. 2018).

The Gunung Sewu Karst of Central Java, Indonesia, represents one of the largest and most geomorphologically complex karst regions in Southeast Asia. Despite its designation as a UNESCO Global Geopark, communities inhabiting this landscape continue to face structural challenges related to water access, soil fertility, and economic marginalization. Under such conditions, biocultural knowledge is not merely a cultural legacy but a functional system that supports everyday survival. Understanding how medicinal plant use operates within this biocultural framework is therefore essential for interpreting human–environment interactions in karst ecosystems.

Traditional medicinal plant use constitutes a central component of ethnobotanical systems in environmentally marginal landscapes. In drylands and karst regions, plant-based remedies frequently serve as primary or complementary healthcare resources due to limited access to formal medical facilities and the high cost of pharmaceutical treatments (Albuquerque et al. 2014). Medicinal plant selection in such environments is strongly influenced by species availability, growth form, regeneration capacity, and ease of harvesting, resulting in characteristic patterns dominated by herbaceous species, renewable plant parts, and simple preparation methods such as decoction (Voeks 2004; Gaoue et al. 2017).

In Indonesia, ethnobotanical research has documented extensive medicinal plant knowledge across lowland forests, agroforestry systems, and montane regions (Sujarwo et al. 2014; Silalahi et al. 2015). However, karst landscapes remain comparatively underrepresented in ethnobotanical studies, despite their ecological distinctiveness and socio-environmental vulnerability. Existing studies from karst regions globally suggest that medicinal plant use reflects both ecological filtering and cultural innovation, producing selective plant repertoires adapted to dry and rocky conditions (Pieroni and Quave 2014; Ferreira-Junior and Albuquerque 2018).

Several ethnobotanical studies have examined medicinal plant use in karst landscapes of southern Java, including Pacitan District (Ammar et al. 2021), Gunung Kidul (Nahdi and Kurniawan 2019), and the Menoreh Karst Area (Igustita et al. 2023). These studies consistently report a high reliance on Zingiberaceae, leaf- and rhizome-based remedies, and decoction as the dominant preparation method. Nevertheless, most focus primarily on species inventories and utilization patterns, with limited integration of ecological context, growth-form composition, and harvesting strategies as adaptive responses to karst-specific constraints. Comparative insights across adjacent karst systems also remain limited, particularly at the household scale.

The present study addresses this gap by examining medicinal plant use as a form of biocultural adaptation in karst villages of the Gunung Sewu Karst Region, Wonogiri District, Central Java. Rather than treating medicinal plants solely as pharmacological resources, this study situates plant use within the broader context of ecological limitation, livelihood strategies, and knowledge transmission. The objectives are to document the diversity of medicinal plants used by local communities, analyze patterns of use in relation to growth forms and harvested plant parts, and interpret these patterns within a biocultural adaptation framework. By integrating ecological characteristics of karst landscapes with ethnobotanical data, this study contributes to a more nuanced understanding of human–environment interactions and provides insights relevant to biodiversity conservation, cultural heritage preservation, and sustainable healthcare strategies in environmentally marginal landscapes. Medicinal plant use in the Gunung Sewu Karst is structured by karst-specific environmental constraints, resulting in a selective dominance of herbaceous species, preferential use of renewable plant parts (leaves and rhizomes), and simple preparation methods (primarily decoction) that function as adaptive, household-based healthcare strategies.

MATERIALS AND METHODS

Study area

The study was conducted in the Gunung Sewu Karst Region, Indonesia, a tropical karst landscape extending across parts of Wonogiri, Gunungkidul, and Pacitan Districts. This region is characterized by extensive limestone formations, rugged topography, and a dense network of sinkholes, caves, and subterranean drainage systems that strongly influence surface hydrology and land use patterns (Figure 1). Surface water availability is highly seasonal, with prolonged dry periods that constrain agricultural activities and household water access.

The environmental conditions of the Gunung Sewu Karst are defined by shallow and discontinuous soils, high rock exposure, and limited soil moisture retention, characteristics typical of limestone landscapes in southern Java (Haryono and Day 2004; Aprilia et al. 2021). These constraints shape vegetation structure, favoring drought-tolerant species, herbaceous plants, and taxa capable of regenerating under nutrient-poor conditions, as widely observed in karst ecosystems of Java and Indonesia (Prabowo et al. 2024; Nahdi and Kurniawan 2019). Local livelihoods are predominantly based on rain-fed agriculture, homegardens, and small-scale livestock rearing, with strong dependence on locally available biological resources for food, medicine, and daily subsistence, a pattern consistently documented in karst communities of Gunung Sewu and adjacent regions (Ammar et al. 2021).

Fieldwork was carried out in two karst villages, Gebangharjo and Glinggang, located within the Wonogiri District of the Gunung Sewu Karst, Central Java, Indonesia. These villages were selected due to their long-established settlement history, active reliance on traditional plant-based practices, and proximity to karst landforms that limit access to conventional health services. The combination of environmental constraints and sustained traditional knowledge makes these villages representative sites for examining biocultural adaptation in karst landscapes.

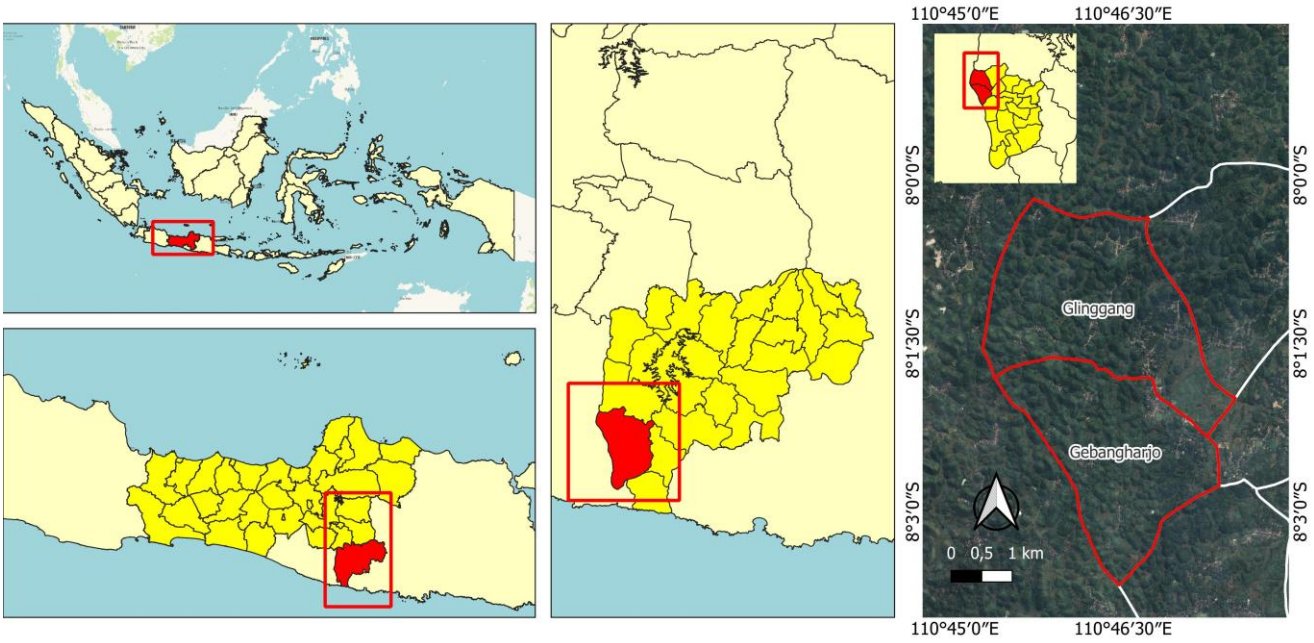

Figure 1. Location of the study area in the Gunung Sewu Karst, Central Java, Indonesia, showing the position of Gebangharjo and Glinggang Villages within the karst landscape

Data collection and ethnobotanical survey

Ethnobotanical data were collected through a combination of semi-structured interviews, field observations, and informal discussions conducted between local researchers and community members, an approach widely applied in ethnobotanical research to capture both documented practices and contextual knowledge (Martin 1995; Albuquerque et al. 2014; Jadid et al. 2020). Informants were selected using purposive sampling, targeting individuals recognized within the community as having knowledge of traditional medicinal plant use, including elderly residents, household caregivers, and local herbal practitioners. This approach ensured that information gathered reflected long-term experiential knowledge rather than incidental plant use, consistent with established ethnobotanical sampling principles (Tongco 2007; Kubiciel-Lodzińska 2021).

Semi-structured interviews were employed to document medicinal plant species, local names, plant parts used, preparation methods, routes of application, and ailments treated. Interviews were conducted in the local language to facilitate clear communication and minimize misinterpretation, as recommended in cross-cultural ethnobotanical studies (Alexiades 1996; Albuquerque et al. 2014). Open-ended questions allowed informants to elaborate on usage practices, contextual meanings, and perceived effectiveness of remedies, while maintaining consistency across interviews. Demographic characteristics of informants, including age group, gender, education level, and primary occupation, were recorded to contextualize knowledge distribution within the community (Table 1), following standard ethnobotanical documentation frameworks (Martin 1995; Navia et al. 2021).

Field observations accompanied interviews to verify plant identity, habitat, and harvesting practices. Plants cited by informants were directly observed in homegardens, agricultural fields, or surrounding karst vegetation. When possible, observations focused on harvesting intensity, plant availability, and regeneration patterns. This triangulation of interview data and field observation strengthened data reliability and ensured that reported medicinal uses were grounded in actual local practices rather than recalled knowledge alone, a procedure commonly recommended to reduce recall bias in ethnobotanical surveys (Alexiades 1996; Albuquerque et al. 2014; Kunwar et al. 2022).

Plant identification and nomenclature

Medicinal plant species were identified through direct field observation based on morphological characters, including growth form, leaf shape, stem structure, inflorescence, and reproductive traits. Field identification was supported by standard regional floras, particularly *Flora of Java* Volumes I-III (Backer and Bakhuizen van den Brink 1963-1968), which remain authoritative references for plant taxonomy in Java. Additional identification guidance was obtained from regional ethnobotanical and botanical literature relevant to tropical Southeast Asia.

To ensure nomenclatural consistency and taxonomic validity, all scientific names used in this study follow currently accepted names as recognized by major global plant taxonomic databases. Scientific names were standardized based on the Plants of the World Online (POWO; https://powo.science.kew.org) and the Global Biodiversity Information Facility (GBIF; https://www.gbif.org), which compile up-to-date

taxonomic treatments and synonymy. Where local or literature-based names corresponded to historical or alternative nomenclature, these were cross-checked against accepted names to avoid the use of outdated or ambiguous taxa.

Synonyms encountered during identification were verified through these databases and are reported only when necessary to clarify taxonomic interpretation or to align local nomenclature with accepted scientific usage. This approach ensures that species names presented in the manuscript are taxonomically valid, internationally recognizable, and comparable with other ethnobotanical studies, while maintaining consistency with regional floristic references.

Data analysis

Ethnobotanical data were organized and analyzed using descriptive approaches to summarize patterns of medicinal plant use within the study area. Reported medicinal uses were first classified into major categories based on the type of ailment treated, plant part used, preparation method, and route of application. This classification facilitated comparison across species and households and allowed the identification of dominant use patterns at the community level (Martin 1995; Alexiades 1996).

Descriptive analysis was applied to quantify the relative contribution of plant families, growth forms, and plant parts used in traditional medicinal practices. Species frequency and use information were tabulated to support transparent presentation of results, while avoiding inferential statistics that require assumptions beyond the scope of the study. Proportional values were calculated to express the distribution of preparation methods, application routes, and disease categories across the recorded species, providing a clear overview of medicinal plant utilization trends (Albuquerque et al. 2014).

All analyses were conducted using simple tabulation and percentage calculations to ensure methodological clarity and reproducibility. This approach is appropriate for exploratory ethnobotanical studies aimed at documenting local knowledge systems and identifying biocultural patterns rather than testing causal hypotheses (de Medeiros et al. 2012).

RESULTS AND DISCUSSION

Demographic characteristics of respondents

A total of 36 respondents representing different genders, age groups, educational backgrounds, and occupations participated in this study (Table 1). The demographic composition reflects the social structure of karst village communities, where traditional knowledge of medicinal plants is unevenly distributed across age and social roles. Informants were predominantly adults, particularly those in the 36-45 years group (27.5%, n = 13) and 56-65 years (20.0%, n = 8), indicating that ethnomedicinal knowledge is mainly retained among individuals with long-term experience in household management and daily subsistence activities.

Both male and female respondents contributed information on medicinal plant use, with female respondents comprising a larger proportion (55.0%, n = 22) compared to male respondents (35.0%, n = 14). Women played a more prominent role in reporting medicinal plant use related to household healthcare, childcare, and food preparation, reflecting their central involvement in domestic health practices. Older respondents generally demonstrated broader knowledge of plant diversity, preparation techniques, and traditional applications, whereas younger respondents aged 15-25 years and 26-35 years each represented only 7.5% (n = 3) of the total sample, suggesting more limited familiarity with traditional medicinal practices.

Educational backgrounds varied among respondents, with the majority having completed senior high school (37.5%, n = 16) or elementary school (32.5%, n = 13). Fewer respondents reported junior high school education (15.0%, n = 6), and only one respondent had attained a university-level education (2.5%, n = 1). These patterns indicate that formal education level does not directly correspond with the depth of ethnobotanical knowledge, which appears to be more strongly associated with lived experience and intergenerational knowledge transmission rather than institutional schooling.

Overall, occupational profiles were dominated by farming and informal livelihood activities closely associated with the karst environment. This demographic context provides an important foundation for interpreting patterns of medicinal plant use and knowledge distribution observed in the Gunung Sewu Karst communities (Table 1).

Diversity of medicinal plant species

A total of 25 medicinal plant species belonging to 16 families were recorded from the karst villages studied (Table 2). The documented species represent a diverse assemblage of plants utilized in household-based traditional medicine under karst environmental constraints. Despite this overall taxonomic diversity, medicinal plant use was unevenly distributed across plant families, indicating selective reliance on taxa that are both ecologically suited to karst conditions and culturally embedded in local health practices.

Table 1. Demographic characteristics of respondents in the Gunung Sewu Karst, Central Java, Indonesia (n = 36)

Parameter	Specification	Freq.	Percentage
Gender	Male	14	35.0%
	Female	22	55.0%
Age (years)	15-25	3	7.5%
	26-35	3	7.5%
	36-45	13	27.5%
	46-55	4	10.0%
	56-65	8	20.0%
	66-75	5	12.5%
Education	Elementary school	13	32.5%
	Junior high school	6	15.0%
	Senior high school	16	37.5%
	University	1	2.5%

The family Zingiberaceae was the most dominant, contributing 8 species (32.0% of the total recorded species). Members of this family were widely cited for their medicinal applications, particularly for digestive disorders, body warming, fatigue reduction, and general health maintenance. The prominence of Zingiberaceae reflects the ecological suitability of rhizomatous herbs to shallow, rocky soils, as well as their cultural familiarity, since many species are commonly cultivated in homegardens and are easily accessible throughout the year. The family Lamiaceae ranked second, represented by 3 species (12.0%), followed by 13 families each represented by a single species (4.0% per family), resulting in a long-tail distribution of medicinal plant diversity (Figure 2).

In terms of growth forms, the recorded medicinal plants comprised herbaceous species (13 species, 52.0%), trees (7 species, 28.0%), climbers (3 species, 12.0%), shrubs (1 species, 4.0%), and succulent herbs (1 species, 4.0%). Herbaceous plants were thus the most frequently utilized growth form, particularly rhizomatous taxa from the Zingiberaceae, which were commonly prepared as decoctions for internal use. Several species were repeatedly mentioned by multiple informants, indicating their key role in the local medicinal system. These include widely cultivated rhizomatous herbs, climbers used primarily for febrile conditions, and tree species whose leaves or fruits are incorporated into household remedies.

The documented species comprised both cultivated plants maintained in homegardens and species obtained from surrounding karst vegetation, indicating a mixed sourcing strategy. This combination of deliberate management and opportunistic use allows households to maintain access to medicinal resources while adapting to the ecological limitations of the karst environment.

The diversity of medicinal plant species recorded in this study reflects a biocultural repertoire shaped by ecological constraints, accessibility, and accumulated traditional knowledge rather than random exploitation of available flora. The selective dominance of particular families and growth forms highlights adaptive patterns of medicinal plant use in the Gunung Sewu Karst landscape.

Table 2. Medicinal plant species used by local communities in the Gunung Sewu Karst, Indonesia (n species = 25)

Family	Scientific name	Local name	Growth form
Acanthaceae	*Strobilanthes crispa* (L.) Blume	*Kejibeling*	Shrub
Aloeaceae	*Aloe vera* (L.) Burm.f.	*Lidah buaya*	Succulent herb
Annonaceae	*Annona squamosa* L.	*Srikaya*	Tree
Basellaceae	*Anredera cordifolia* (Ten.) Steenis	*Binahong*	Climber
Campanulaceae	*Hippobroma longiflora* (L.) G.Don	*Kitolod*	Herbaceous
Fabaceae	*Cassia siamea* Lam.	*Johar*	Tree
Lamiaceae	*Ocimum basilicum* L.	*Kemangi*	Herbaceous
Lamiaceae	*Orthosiphon aristatus* (Blume) Miq.	*Kumis kucing*	Herbaceous
Lamiaceae	*Plectranthus amboinicus* (Lour.) Spreng.	*Bangun-bangun*	Herbaceous
Lauraceae	*Persea americana* Mill.	*Alpukat*	Tree
Meliaceae	*Swietenia mahagoni* (L.) Jacq.	*Mahoni*	Tree
Menispermaceae	*Tinospora crispa* (L.) Hook.f. & Thomson	*Brotowali*	Climber
Moraceae	*Antiaris toxicaria* Lesch.	*Upas*	Tree
Moringaceae	*Moringa oleifera* Lam.	*Kelor*	Tree
Piperaceae	*Piper betle* L.	*Sirih*	Climber
Poaceae	*Cymbopogon citratus* (DC.) Stapf	*Serai*	Herbaceous
Rutaceae	*Citrus aurantiifolia* (Christm.) Swingle	*Jeruk nipis*	Tree
Zingiberaceae	*Alpinia galanga* (L.) Willd.	*Lengkuas*	Herbaceous
Zingiberaceae	*Curcuma aeruginosa* Roxb.	*Temu ireng*	Herbaceous
Zingiberaceae	*Curcuma longa* L.	*Kunyit*	Herbaceous
Zingiberaceae	*Curcuma zanthorrhiza* Roxb.	*Temulawak*	Herbaceous
Zingiberaceae	*Curcuma zedoaria* (Christm.) Roscoe	*Kunyit putih*	Herbaceous
Zingiberaceae	*Kaempferia galanga* L.	*Kencur*	Herbaceous
Zingiberaceae	*Zingiber officinale* Roscoe	*Jahe*	Herbaceous
Zingiberaceae	*Zingiber officinale* var. *rubrum*	*Jahe merah*	Herbaceous

Growth forms and plant parts used

Medicinal plant use in the Gunung Sewu Karst showed clear patterns related to plant growth forms and harvested plant parts, reflecting adaptive strategies under karst environmental constraints. Herbaceous species constituted the dominant growth form, accounting for 52.0% of the recorded medicinal plants (13 of 25 species), followed by tree species at 28.0% (7 species) (Table 2; Figure 3.A). Climbers contributed 12.0% (3 species), while shrubs and succulent herbs were each represented by a single species (4.0% each). The dominance of herbaceous plants indicates a preference for taxa that are easily cultivated, regenerate rapidly, and are able to persist under shallow soils and limited moisture conditions typical of karst landscapes.

Tree species, although fewer in number, played a complementary role in traditional medicine, particularly through the use of leaves or fruits that can be harvested without causing permanent damage to the plant. Climbers

were used more selectively and were often associated with specific medicinal applications, while shrubs and succulent herbs contributed only marginally to the overall medicinal repertoire. The relatively low representation of woody growth forms likely reflects both ecological constraints and practical harvesting considerations in rocky karst terrain.

Analysis of plant parts used revealed a strong reliance on renewable plant organs (Figure 3.B). Leaves were the most frequently harvested plant part, comprising 50.0% of recorded uses, owing to their year-round availability, ease of collection, and minimal impact on plant survival. Rhizomes represented the second most commonly used plant part (30.8%), particularly among herbaceous species in the Zingiberaceae, and were closely associated with decoction-based remedies for internal ailments. Other plant parts were used less frequently, including fruits (7.7%), flowers (3.8%), stems (3.8%), and roots (3.8%), typically for specific therapeutic purposes.

Taken together, these patterns indicate that a balance between therapeutic effectiveness and sustainable harvesting practices shapes medicinal plant use in the Gunung Sewu Karst. The predominance of herbaceous species and renewable plant parts such as leaves and rhizomes reflects a biocultural adaptation that minimizes ecological impact while maintaining access to essential household healthcare resources.

Preparation methods, applications, and treated ailments

Traditional medicinal plant use in the Gunung Sewu Karst is characterized by a limited number of preparation techniques and application routes, reflecting practical adaptation to household conditions and environmental constraints. Decoction was the dominant preparation method, accounting for 80.0% of all recorded uses (20 of 25 species) (Table 3; Figure 4.A). This method was applied to a wide range of plant parts, including leaves, rhizomes, stems, and fruits, enabling the extraction of bioactive compounds using simple equipment and readily available water sources. Other preparation techniques were reported less frequently, including crushing (12.0%, 3 species) and raw consumption (8.0%, 2 species), and were generally associated with specific plant species and targeted ailments.

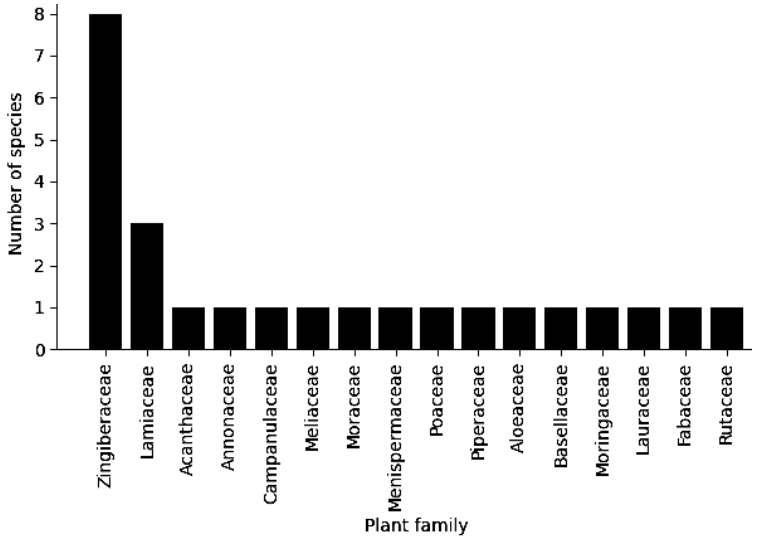

Figure 2. Diversity of medicinal plant species recorded in the Gunung Sewu Karst, Central Java, Indonesia, illustrating family-level composition and dominant plant families

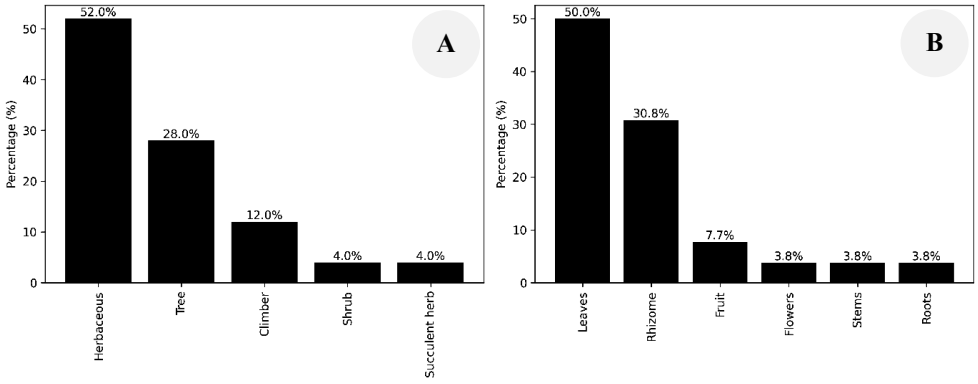

Figure 3. Distribution of growth forms and plant parts used in traditional medicinal practices in the Gunung Sewu Karst, Central Java, Indonesia, expressed as percentages of the total recorded species. A. Growth forms of medicinal plant species, B. Plant parts used

Oral administration overwhelmingly dominated the application routes, representing 88.0% of reported uses (22 of 25 species) (Figure 4.B). This pattern indicates that medicinal plants are primarily used for internal health maintenance and treatment of systemic conditions. Topical application was reported for only 8.0% of species (2 species), mainly for treating burns, wounds, or envenomation, while eye drops accounted for 4.0% (1 species) and represent a highly specific, culturally embedded practice involving fresh plant material. The distribution of preparation methods and application routes demonstrates a strong preference for techniques that are easy to perform, require minimal processing, and can be readily integrated into daily household routines.

The ailments treated using medicinal plants were largely mild to moderate health conditions commonly encountered in everyday life (Figure 5). Respiratory ailments were the most frequently reported category (16.0%, 4 species), including cough, cold, and flu, followed by digestive disorders (12.0%, 3 species), such as stomach ache and appetite enhancement, and skin-related conditions (12.0%, 3 species), including burns, wounds, and rashes. General health maintenance, including body warming and non-specific herbal remedies, accounted for 12.0% (3 species) of recorded uses. More specialized treatments, such as remedies for postpartum care, fever, anemia, or snake bite, were reported less frequently but remain culturally significant within the local medical system.

The dominance of decoction-based preparation and oral application, coupled with the emphasis on treating common ailments, highlights the role of medicinal plants as a first-line healthcare resource in karst villages. These practices reflect the functional integration of traditional medicine into household health strategies rather than reliance on specialized or ritualized treatments.

Discussion

Biocultural adaptation in karst environments

The patterns of medicinal plant use documented in the Gunung Sewu Karst reflect a clear form of biocultural adaptation shaped by long-term interactions between local communities and an environmentally constrained landscape. Karst environments are characterized by shallow soils, rapid subsurface drainage, seasonal water scarcity, and pronounced microhabitat heterogeneity, all of which limit plant establishment and strongly influence local resource management strategies (Ford and Williams 2007; Day 2010). Under such conditions, biocultural knowledge functions as an adaptive system that integrates ecological constraints with culturally embedded practices, enabling households to maintain resilience under persistent environmental stress (Gadgil et al. 1993; Berkes 2012).

Table 3. Preparation methods, application routes, and diseases treated using medicinal plants in the Gunung Sewu Karst, Central Java, Indonesia

Scientific name	Plant part used	Preparation method	Application	Treated ailment
Strobilanthes crispa (L.) Blume	Leaves	Crushed	Oral	General herbal medicine
Aloe vera (L.) Burm.f.	Leaves	Crushed	Topical	Burns
Annona squamosa L.	Leaves	Decoction	Oral	Stomach ache
Anredera cordifolia (Ten.) Steenis	Leaves	Decoction	Oral	Wound healing
Hippobroma longiflora (L.) G.Don	Leaves	Raw	Eye drops	Sore eyes
Cassia siamea Lam.	Leaves	Decoction	Oral	Malaria
Ocimum basilicum L.	Leaves	Raw	Oral	Bad breath
Orthosiphon aristatus (Blume) Miq.	Flower	Crushed	Oral	Skin rash, itching, nosebleed
Plectranthus amboinicus (Lour.) Spreng.	Leaves	Decoction	Oral	Flu
Persea americana Mill.	Leaves	Decoction	Oral	Hypertension
Swietenia mahagoni (L.) Jacq.	Fruit	Decoction	Oral	Postpartum care
Tinospora crispa (L.) Hook.f. & Thomson	Stem	Decoction	Oral	Fever
Antiaris toxicaria Lesch.	Leaves	Decoction	Topical	Snake bite
Moringa oleifera Lam.	Leaves	Decoction	Oral	Anemia
Piper betle L.	Leaves	Decoction	Oral	Cough
Cymbopogon citratus (DC.) Stapf	Leaves	Decoction	Oral	Cold
Citrus aurantiifolia (Christm.) Swingle	Fruit	Raw	Oral	Cough
Alpinia galanga (L.) Willd.	Rhizome	Decoction	Oral	Stomach ache
Curcuma aeruginosa Roxb.	Rhizome	Decoction	Oral	Menstrual pain
Curcuma longa L.	Rhizome	Decoction	Oral	General herbal medicine
Curcuma zanthorrhiza Roxb.	Rhizome	Decoction	Oral	Appetite enhancer
Curcuma zedoaria (Christm.) Roscoe	Rhizome	Decoction	Oral	Antioxidant
Kaempferia galanga L.	Rhizome	Decoction	Oral	Muscle pain
Zingiber officinale Roscoe	Rhizome	Decoction	Oral	Body warming
Zingiber officinale var. *rubrum*	Rhizome	Decoction	Oral	Antioxidant

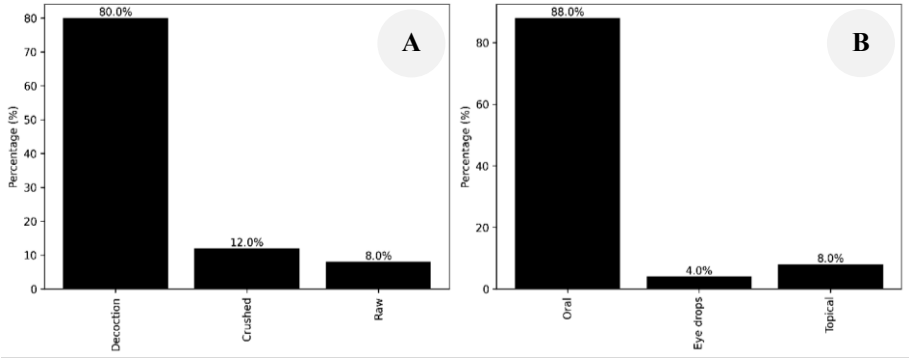

Figure 4. Preparation and application methods of medicinal plants used by local communities in the Gunung Sewu Karst, Central Java, Indonesia, showing the dominance of decoction-based preparation and oral administration. A. Preparation methods, B. Application routes

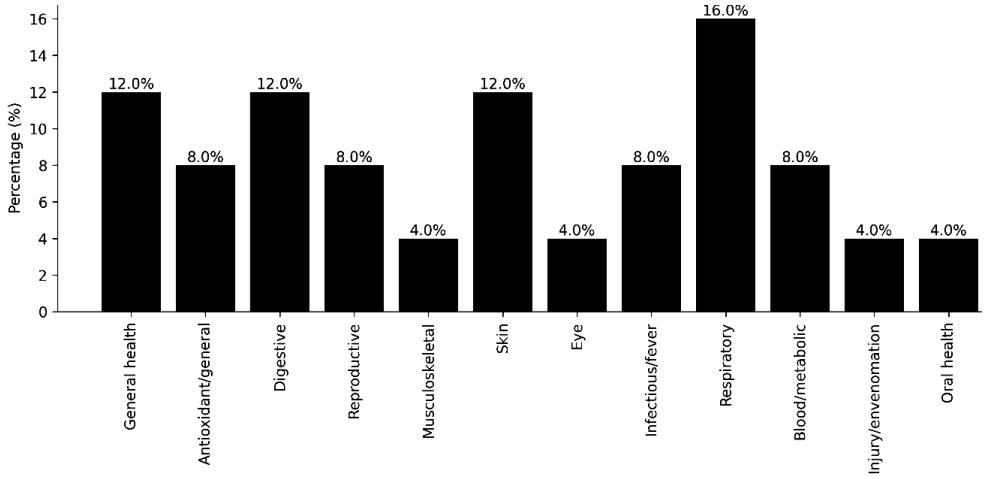

Figure 5. Categories of ailments treated using medicinal plants in the Gunung Sewu Karst, Central Java, Indonesia, highlighting the predominance of treatments for mild to moderate health conditions

The dominance of herbaceous medicinal plants, accounting for 52.0% of the recorded species, together with the preferential use of renewable plant parts such as leaves (50.0%) and rhizomes (30.8%), illustrates a strategic response to the ecological limitations of karst environments (Figure 5). Herbaceous taxa are favored due to their rapid growth, ease of cultivation in shallow and rocky soils, and strong regenerative capacity following harvesting, making them reliable resources in landscapes where woody vegetation is less accessible or slower to recover. Tree species, although contributing a smaller proportion (28.0%), played a complementary role, while climbers (12.0%), shrubs (4.0%), and succulent herbs (4.0%) represented more specialized components of the local medicinal flora. Similar dominance of herbaceous species has been reported from other karst and dryland regions, where medicinal plant selection is shaped by ecological filtering and long-term cultural adaptation processes (Voeks 2004; Gaoue et al. 2017; Pieroni and Quave 2014; Quave and Pieroni 2015).

The strong reliance on leaves as the primary harvested plant part further reflects adaptive harvesting strategies that minimize ecological impact while ensuring continuous access to medicinal resources. Leaf harvesting is widely recognized as a sustainable practice in traditional medicine systems, particularly in environments where intensive exploitation of roots, bark, or woody tissues could result in rapid resource depletion (Cunningham 2001; de Albuquerque et al. 2014). In the Gunung Sewu Karst, this pattern suggests the presence of an implicit conservation ethic embedded within everyday medicinal practices rather than reliance on formalized management regulations.

Rhizome use, especially among herbaceous taxa of the Zingiberaceae, represents a complementary adaptive strategy that balances therapeutic effectiveness with accessibility. Rhizomatous species are commonly cultivated in homegardens, thereby reducing pressure on wild populations and reinforcing the integration of medicinal plant use into household agroecological systems. Comparable patterns have been documented in karst-influenced agroecosystems of southern China and mainland Southeast Asia, where medicinal plants are actively maintained within managed landscapes as part of local health and subsistence strategies (Srithi et al. 2009; de Medeiros et al. 2012).

These findings demonstrate that medicinal plant use in the Gunung Sewu Karst is not random but constitutes a coherent biocultural adaptation to environmental limitation. The novelty of this study lies in explicitly linking growth-form composition and harvested plant parts to karst ecological constraints, thereby framing traditional medicinal practices as adaptive responses rather than isolated cultural traditions. This perspective contributes to a growing body of biocultural research emphasizing the critical role of local knowledge systems in sustaining human well-being in environmentally marginal landscapes (Caillon et al. 2017; Sterling et al. 2017).

Ecological constraints and medicinal plant selection

Ecological constraints inherent to karst landscapes play a decisive role in shaping medicinal plant selection and use. The dominance of herbaceous species documented in the Gunung Sewu Karst (52.0% of recorded species) reflects strong environmental filtering imposed by shallow soils, high rock exposure, limited nutrient availability, and pronounced seasonal drought. Under such conditions, herbaceous plants are ecologically favored over woody taxa because they require less soil depth, exhibit shorter growth cycles, and are able to rapidly exploit transient moisture availability following rainfall events (Ford and Williams 2007; Goldscheider et al. 2020). These ecological traits directly influence which plant species remain accessible to local communities and are subsequently incorporated into traditional medicinal systems.

Herbaceous dominance in medicinal plant repertoires has been widely documented in environmentally constrained systems, including karst, dryland, and mountainous regions. Studies from karst areas in the Mediterranean, the Balkans, and Southeast Asia consistently report medicinal knowledge concentrated on fast-growing herbs and climbers that occur close to settlements and along disturbed microhabitats (Srithi et al. 2009; Pieroni and Quave 2014). In the Gunung Sewu Karst, the prevalence of herbaceous medicinal plants suggests a selective process in which ecological availability and cultural preference converge, reinforcing the adaptive nature of medicinal plant use under resource limitation rather than random exploitation of the surrounding flora.

Sustainable harvesting practices further mediate medicinal plant selection in karst environments. The strong reliance on leaves as the primary harvested plant part (50.0% of recorded uses) reflects an implicit strategy to minimize ecological impact while maintaining therapeutic efficacy. Leaf harvesting is generally less destructive than the extraction of roots, bark, or whole plants, allowing individuals to continue growing and contributing to future harvests (Cunningham 2001; Gaoue et al. 2017). In karst landscapes, where edaphic limitations and water scarcity may constrain plant regeneration, such practices are particularly important for ensuring long-term availability of medicinal resources.

The integration of medicinal plants into homegardens and other managed spaces further supports sustainable use under ecological constraints. Many herbaceous species with medicinal value are deliberately cultivated or semi-managed near households, reducing dependence on wild populations and buffering against environmental variability. Comparable management strategies have been documented in karst-influenced agroecosystems of China, Thailand, and Vietnam, where medicinal plant cultivation functions simultaneously as a conservation measure and a household health strategy (de Medeiros et al. 2012; Ferreira-Junior and Albuquerque 2018). Together, these patterns indicate that medicinal plant selection in the Gunung Sewu Karst is shaped not only by ecological constraints but also by culturally embedded practices that promote sustainable and resilient resource use.

Comparison with other karst and non-karst regions

Comparative analysis indicates that medicinal plant use in the Gunung Sewu Karst shares important structural similarities with ethnobotanical systems documented in other karst regions, while simultaneously exhibiting distinctive local characteristics. Studies from Mediterranean karst landscapes and the Balkan Peninsula consistently report a strong reliance on herbaceous species and leaf-based remedies, reflecting convergent adaptive responses to shallow soils, limited water retention, and high substrate heterogeneity (Pieroni and Quave 2014; Quave and Pieroni 2015). Comparable patterns have also been observed in karst areas of southern China and mainland Southeast Asia, where medicinal plant repertoires are shaped by ecological filtering, proximity to settlements, and long-term cultural familiarity with locally available taxa (Srithi et al. 2009; de Medeiros et al. 2012).

Within Java, ethnobotanical studies conducted in karst landscapes adjacent to Gunung Sewu, including Pacitan District and Gunung Kidul, reveal similar functional patterns despite differences in species richness. Research from Pacitan karst villages documented a larger number of medicinal plant species, yet reported comparable dominance of Zingiberaceae, frequent use of leaves and rhizomes, and decoction as the principal preparation method (Ammar et al. 2021). Likewise, studies from Gunung Kidul emphasize herb-based *jamu* formulations and household-level reliance on cultivated or semi-cultivated species, reflecting parallel adaptive strategies under karst soil constraints (Nahdi and Kurniawan 2019). These similarities suggest that ecological limitation, rather than floristic availability alone, plays a decisive role in shaping medicinal plant use across southern Javanese karst systems.

The medicinal plant system of the Gunung Sewu Karst is nevertheless distinguished by its strong integration of cultivated and semi-cultivated species within household spaces. Compared with karst landscapes in coastal settings, such as the Prigi Bay area in Trenggalek—which represents a coastal karst system influenced by marine humidity, deeper colluvial soils, and agroforestry-oriented homegardens—Gunung Sewu exhibits a more constrained yet selectively managed plant repertoire. While studies from Prigi report high medicinal plant diversity embedded in complex homegarden structures (Agustina et al. 2022), the Gunung Sewu Karst favors fewer, functionally reliable species adapted to drier inland karst conditions. This

contrast highlights how variation within karst types (inland versus coastal karst) further shapes biocultural strategies of medicinal plant selection and management.

In contrast to non-karst forest-based ethnobotanical systems in Indonesia—such as lowland rainforests and montane ecosystems—where medicinal plant use often includes a higher proportion of woody species and harvesting of bark or roots (Sujarwo et al. 2014; Silalahi et al. 2015), the Gunung Sewu Karst supports a simpler vegetation structure. This structural limitation promotes medicinal practices that emphasize functional efficiency, accessibility, and renewable plant parts rather than maximizing taxonomic richness. Similar patterns have been observed in other environmentally marginal systems, where ethnobotanical knowledge prioritizes species that are consistently available and easy to manage under variable environmental conditions (Voeks 2004; Gaoue et al. 2017).

The distinctiveness of the Gunung Sewu Karst, therefore, lies not merely in its species composition but in the way biocultural knowledge mediates between ecological scarcity and household healthcare needs. Unlike some karst regions where traditional medicinal practices are declining due to urbanization or increased reliance on biomedical healthcare, communities in the Gunung Sewu Karst continue to actively apply plant-based remedies as part of everyday health management. This persistence reflects both cultural continuity and ongoing environmental necessity. By situating Gunung Sewu within a comparative framework that includes inland karst, coastal karst, and non-karst systems, this study underscores its value as a model landscape for understanding how biocultural adaptations emerge, persist, and remain functionally relevant under long-term ecological constraint (Caillon et al. 2017; Sterling et al. 2017).

In conclusion, this study documents medicinal plant use in the Gunung Sewu Karst as a biocultural adaptation shaped by long-term interaction between local communities and an environmentally constrained landscape. A total of 25 medicinal plant species belonging to 16 families were recorded, with clear dominance of herbaceous taxa (52.0%) and a marked reliance on Zingiberaceae (32.0% of recorded species). Medicinal practices preferentially utilized renewable plant parts, particularly leaves (50.0%) and rhizomes (30.8%), reflecting adaptive harvesting strategies suited to shallow soils, seasonal water scarcity, and limited nutrient availability characteristic of karst environments. These patterns indicate ecological filtering in combination with culturally embedded strategies that emphasize accessibility, renewability, and household-based healthcare.

Preparation and application patterns further support this adaptive interpretation. Decoction was the dominant preparation method (80.0% of species), and oral administration accounted for 88.0% of reported uses, indicating that medicinal plants primarily function as first-line household healthcare resources. Rather than representing isolated cultural traditions, medicinal plant practices in Gunung Sewu constitute a coherent system that integrates ecological constraint, sustainable harvesting, and intergenerational knowledge transmission. By explicitly linking growth forms, harvested plant parts, and preparation methods to karst environmental conditions, this study advances a biocultural perspective on ethnobotany in marginal ecosystems. These findings contribute to ethnobotanical research by highlighting karst landscapes as important yet underexplored settings for biocultural adaptation.

This study is limited by its descriptive analytical approach, restricted geographic scope (two villages), and moderate sample size (36 respondents), which constrain broader generalization and prevent causal inference. In addition, the temporal dynamics of knowledge transmission and changes in medicinal plant use were not assessed. Future research should incorporate comparative studies across multiple karst systems, longitudinal analyses of knowledge change, and quantitative indices (e.g., use value, fidelity level) to strengthen inference. Integrating ethnobotanical data with ecological monitoring and socio-economic assessment will further clarify how traditional medicinal knowledge contributes to resilience, conservation, and sustainable healthcare strategies in environmentally marginal karst landscapes.

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