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Ethnobotanical knowledge and medicinal plant diversity in mountain region of district Bhimber, Azad Jammu and Kashmir

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ABSTRACT: Medicinal plant diversity and traditional ethnobotanical knowledge were investigated among marginalized populations inhabiting a transboundary border region. Despite their ecological richness and cultural depth, such areas remain understudied due to political sensitivities and restricted access, resulting in the loss of valuable knowledge about medicinal plants. The research focused on documenting wild medicinal plant diversity, recording traditional uses, and evaluating their relevance for conservation based on indigenous knowledge systems. Fieldwork was conducted from December 2021 to March 2022 across selected sites in the Samahni subdivision of Azad Jammu and Kashmir. A total of 133 medicinal plant species belonging to 58 families were documented. The most dominant families were Asteraceae (12 species), Fabaceae (9 species), and Lamiaceae (7 species). Herbs accounted for most growth forms (64%), followed by trees (18%), shrubs (15%), ferns (2%), and a single climber (1%). Leaves and whole plants were the most frequently used parts, and the infusion was the most common preparation method. Plants were used to treat 17 disease categories, with the highest number addressing digestive issues, respiratory problems, and liver ailments. Quantitative indices showed strong cultural consensus for some species, including *Citrullus colocynthis* (L.) Schrad, *Ziziphus jujuba* Mill, and *Morus nigra* L, showing their ethnomedicinal consistency. Informant Consensus Factor (ICF) values were most prominent for hypertension (0.89), pain (0.89), diabetes (0.88), and blood disorders (0.85), showing strong agreement among local knowledge bearers. The research concludes that mountain communities possess rich yet under documented ethnomedicinal knowledge, highly attuned to their environment and healthcare needs, and guided by informal conservation practices such as the selective use of aerial parts and minimal harvesting of roots to ensure plant sustainability.

KEY WORDS: cultural consensus, ethnobotany, indigenous knowledge, medicinal plants, traditional medicine.

INTRODUCTION

The Himalayan ecosystem is a well-known hotspot of medicinal plant diversity worldwide, with its varied habitats harboring various species of established therapeutic utility (Abdallah *et al*., 2023; Manzoor *et al*., 2023). Wild medicinal plants are especially prized for their efficacy, availability, and strong cultural importance in traditional healing practices (Muhammad *et al*., 2025; Zaman *et al*., 2025). Though significant, most of these plant species remain under-explored and inadequately researched for their conservation, distribution, and customary applications (Gillani *et al*., 2024; Guo *et al*., 2025). Sustainable management of medicinal plant genetic resources is now imperative, especially in areas where habitat destruction, climate change, and over-extraction threaten increasing hazards (Haq *et al*., 2024).

Traditional lore about the use of medicinal plants is the foundation of indigenous and local health systems (Derso *et al*., 2024). Handed down orally from generation to generation, it encompasses the identification, harvesting, preparation, therapeutic application, dosage, and cultural importance of medicinal plants (El-Ramady *et al*., 2022; Ssenku *et al*., 2022). Ethnobotany, being an interdisciplinary science, aims at grasping the intricate relationships between humans and plants in these cultural systems (Nolan and Turner, 2011). In marginalized and rural populations, especially in ecologically fragile zones, ancient ethnomedicinal knowledge is a utilitarian healthcare resource as well as an empirical body of wisdom influenced over centuries by ecological understanding (Du *et al*., 2024; Jabeen *et al*., 2024). This traditional pharmacopoeia is especially crucial where allopathic healthcare access remains constrained or prohibitively costly (Sharma *et al*., 2022; Scherrer *et al*., 2023). Healers, elders, and local experts are key to maintaining this medicinal heritage, serving as physicians and pharmacists to their respective communities (Liu *et al*., 2024; Lou *et al*., 2024). Maintenance of ethnobotanical knowledge is now increasingly challenged by the decline of indigenous languages, land-use change, rural-to-urban migration, and diminishing interest among

younger generations (Coombs *et al*., 2022; Waheed *et al*., 2023). Without proper documentation, a lot of this precious information is in danger of being lost forever. Scientific involvement not only helps to ensure the preservation of indigenous health practice but also yields potential new species and compounds of pharmacological interest (Fajinmi *et al*., 2023; Haq *et al*., 2023).

Border areas around the globe are often inhabited by culturally, linguistically, and ecologically related groups separated by modern political frontiers (Paasi, 2022). Transboundary populations have shared ancestry, ecological information, and subsistence strategies that persist despite geopolitical separation (Mattalia *et al*., 2021; Yang *et al*., 2025). Political frontiers created through colonization, conflict, or administrative shifts have severed administration as well as the persistence of cultural and medicinal knowledge systems (Arshad *et al*., 2024). Despite this, the traditional exploitation of wild medicinal plants still occurs in most of these areas, maintained through oral traditions, seasonality of mobility, and age-old cultural customs (Fontana *et al*., 2022). In most borderlands with poor development and poor healthcare facilities, local communities rely mostly on natural resources locally available for basic healthcare (Gizaw *et al*., 2022). Medicinal plants are essential in such environments for healthcare as well as the maintenance of cultural identity (Eshete and Molla 2021; Haq *et al*., 2023a). Their practice is deeply embedded in local languages, religiosity, and ecological understanding, creating a robust system of biocultural heritage (Marques *et al*., 2021; Gong *et al*., 2024). In addition, most border areas have peculiar or endemic plant species whose documentation has not yet been completed in scientific reports or conservation efforts (Krigas *et al*., 2022; Khoja *et al*., 2024). Although they have the potential to expose neglected medicinal uses and species, border areas are under-studied as a result of accessibility constraints, political tensions, and institutional shortcomings (Luo *et al*., 2024; Ungar and Seymour, 2024).

Despite being rich in ecological and cultural resources, the Indo-Pak border is poorly explored ethnobotanically because of political sensitivities, limited access, and security issues, leading to significant gaps in the documentation of traditional medicinal knowledge (Arshad *et al*., 2020). The Samahni Valley along the Line of Control is a prime example of a politically underprivileged and underdeveloped area where the population is cut off from mainstream healthcare and education systems. This isolation has deepened the dependency on ethnomedicinal knowledge, which is maintained through oral transmission and still forms the core of primary healthcare. In these areas, there is a pressing requirement for holistic, community-based documentation of wild medicinal plant usage that, in addition to recording species diversity and therapeutic applications, provides insights into cultural continuity and conservation concerns in these fragile regions. In response to these lacunae, the current research was conducted with two main objectives: (1) to chronicle the range of wild medicinal plants utilized by marginalized groups within a Himalayan border area. (2) to investigate traditional knowledge systems and cultural practices about medicinal plant use, focusing on the role of indigenous knowledge in primary healthcare. Unlike other Western Himalayan surveys, this study uniquely examines how political marginalization influences the persistence, adaptation, and cultural transmission of indigenous therapeutic practices, offering new insights into the resilience of biocultural knowledge in transboundary settings.

MATERIALS AND METHODS

Study area

The ethnomedicinal survey was carried out in the Samahni Valley, a backward and remote subdivision of District Bhimber, Azad Jammu and Kashmir (AJK), Pakistan. Samahni is geographically situated along the Line of Control (LOC) at 33.77°N and 74.1°E with an average elevation of around 675 meters (2,280 feet) above sea level (Fig. 1). This hilly area, bordered by Bhimber and Mirpur districts, is approximately 55 km long and 10 km wide (Khanum *et al*., 2024). It borders the Indian-administered Rajouri district in Jammu and Kashmir to the north and northeast. The valley is dominated by a combination of broken terrain and pine-covered hills, mostly consisting of dry subtropical Chir pine forests (*Pinus roxburghii*) at the higher elevations and broad-leaved thorn forests in the plains. Samahni has a warm-temperate climate with dry, hot summers and comparatively cold winters. Most of the total annual rainfall (about 974 mm) in the region comes during the monsoon season in July and August, with an average annual temperature of about 23.6°C (Khanum *et al*., 2024). The ecological variation is reflected by the rich floristic composition of the area that sustains numerous herbs, shrubs, and trees utilized locally for medicinal, nutritional, and economic reasons. The research investigated two culturally and ecologically meaningful locations in Samahni in particular: Jhandi Chontra and Baghsar. Jhandi Chontra, 17 km from Bhimber and 67 km from Mirpur, is not only a domestic tourist destination but also a place of religious significance because of the shrine of Sufi saint Sheikh Baba Shadi Shaheed. On the other hand, Baghsar, at a higher altitude of about 975 meters (3,353 feet), is characterized by the ancient Mughal-era Baghsar Fort, adding to the region's cultural heritage.

Field surveys, plant collection, and identification

Ethnobotanical fieldwork was conducted between December 2021 and March 2022 in selected locations within the Samahni subdivision of District Bhimber,

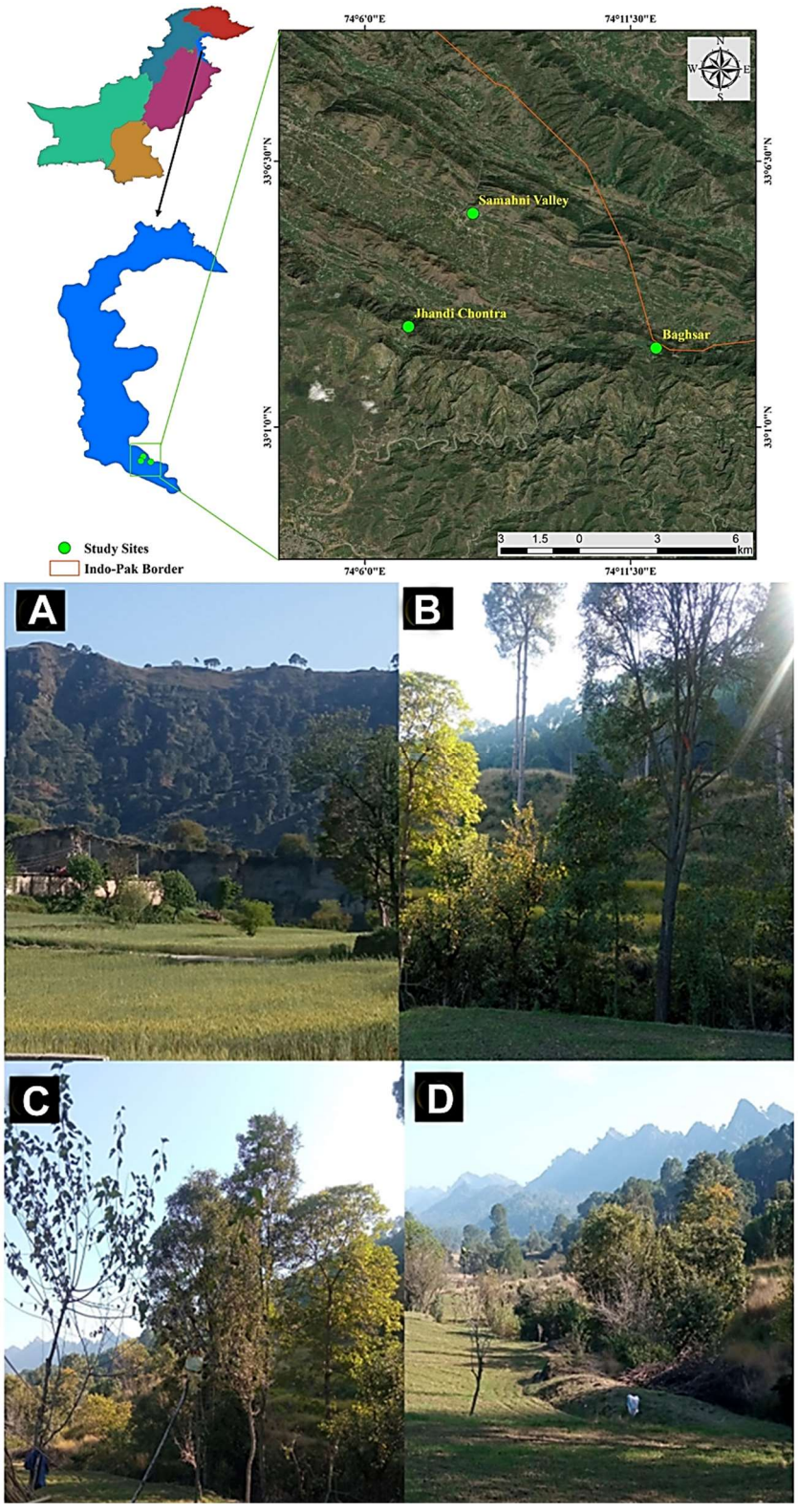

Fig. 1. Geographical location of the study sites in the border area of Azad Jammu and Kashmir, Pakistan. The inset map indicates the general location within the country, whereas the enlarged satellite image indicates the particular ethnobotanical survey areas: Samahni Valley, Jhandi Chontra, and Baghsar. The Indo-Pak border is indicated in red. Featured landscape views of the study area include: **A.** Border communities surrounded by adjacent croplands; **B.** A forested slope dominated by mature conifers; **C.** Agroforestry practices showcasing mixed vegetation alongside cultivated plots; and **D.** Agricultural fields and grassy terrain along the border, reflecting diverse topography.

Azad Jammu and Kashmir (Fig. 1). The primary sites included the villages of Jhandi Chontra and Baghsar, with additional data gathered from surrounding communities such as Jandala and Chahi. These areas, characterized by rich floral diversity and situated near the Indo-Pak border, were selected due to their ecological richness and strong continuity of traditional medicinal knowledge. Field surveys were carried out systematically to document wild medicinal plant species used by the local population. Specimens were collected in the field, preferably during the flowering or fruiting stages to ensure accurate identification. Each plant was photographed in situ using a digital camera to capture morphological details and habitat context. Collected specimens were pressed and preserved following standard herbarium techniques. Initial identification was conducted using regional botanical references, including the Flora of Pakistan (https://www.tropicos.org/Project/Pakistan), and verified through cross-referencing with international databases such Plants of the World Online (https://powo.science.kew.org/). Confirmed voucher specimens were deposited in the herbarium of Lahore College for Women University for future reference.

Ethnobotanical interviews and data collection

Ethnomedicinal data were collected through semi-structured interviews, group discussions, and participatory observation involving 79 informants (48 males and 31 females) selected through convenience sampling. Convenience sampling was employed due to the region's political sensitivity, restricted access, and limited mobility (Waheed *et al*., 2023a). This approach allowed researchers to engage with knowledgeable informants who were locally available and willing to participate (Haq *et al*., 2024a). Informants were aged between 30 and 80 years and included a diverse range of local knowledge holders such as farmers, housewives, midwives, traditional healers, and herbalists. Prior informed consent was obtained verbally from all participants before interviews. Ethical approval for this study was granted by the Ethics Committee of Lahore College for Women University. The research was conducted following the ethical principles outlined in the International Society of Ethnobiology (ISE) Code of Ethics. The interviews were carried out in local Punjabi and Pahari languages to achieve clarity and cultural sensitivity. A field-tested questionnaire, adapted from Heinrich *et al*., (2009), was used to collect information on plant species employed, parts used, preparation methods, modes of administration, and the specific ailments treated. Local names, preparation details, and contextual information such as harvesting practices and belief systems related to plant use were also documented wherever possible. In this study, paste refers to plant material crushed or ground and mixed with a small amount of liquid (e.g., water, milk, or oil) before topical application; poultice denotes softened or heated plant matter applied directly or wrapped in cloth and placed on the affected area; whereas direct administration involves the use of raw plant parts consumed or applied without further processing. Responses were documented in field notes, audio files, and photographs to ensure authenticity and precision. The multi-modal recording method follows the recommendation of Ribeiro *et al*., (2017) and produces an extensive ethnographic record.

Data analysis

Quantitative analysis of ethnobotany was done by employing selected indices to measure the relative importance and cultural significance of medicinal plant species. The Relative Frequency of Citation (RFC) was used to identify the percentage of informants citing each plant species, reflecting its popularity and salience in local medicine practice (Ssenku *et al*., 2022). The Relative Frequency of Citation (RFC) was employed to assess the importance and popularity of each plant species among informants. RFC was calculated using the formula:

$$RFC = \frac{FC}{N}$$

where FC is the number of informants who mentioned the use of a particular species, and N is the total number of informants participating in the survey.

The Use Value (UV) index was employed to assess the general utility of a given species based on the variety of uses mentioned by informants (Albuquerque *et al*., 2006). The relative importance of uses of various plant species is calculated by their use value (UV) by the formula;

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

UV= usage value of specific species
Ui = number of uses that recorded by informants
N= total number of informants who reported that species.

Informant consensus factor (ICF) for different categories of ailments was obtained to examine the homogeneity or consistency of informants' knowledge regarding a specific therapy for a specific ailment. It is applied to point out plants of cultural importance and consensus in medicinal plant use against specific disorders (Trotter and Logan, 2019). The ICF value is between 0 and 1. If the value is near 1, it shows that the respondents are highly concordant in the use of taxa within a disease category (Tugume *et al*., 2016). The ICF value was calculated using the formula;

$$ICF = \frac{N_{ur} - N_t}{N_{ur} - 1}$$

N_{ur}= total number of uses reported for a specific category of disease
N_t= number of taxa reported for a specific category of disease

The spatial position of study sites and the distribution of the area in space were visualized with ArcGIS 10.8 to generate an extensive map of fieldwork locations and their distance from the Indo-Pak border. Statistical analysis and visualization, such as chord diagrams and PCA biplots, were conducted using R software (version

4.2.1; R Core Team, 2022). The 'circlize' package was used to generate chord diagrams displaying associations between plant species, habits of growth, and medicine consumption (Gu *et al*., 2014). R 'factoextra' package was used to perform Principal Component Analysis to determine patterns of plant use by disease classes and preparation process (Kassambara and Mundt, 2017).

RESULTS

Demographic profile of respondents

A total of 79 informants participated in the ethnobotanical survey, comprising 48 males (60.75%) and 31 females (39.24%). On average, male informants mentioned 21 medicinal plant species, whereas female informants cited an average of 17 species. The majority of respondents were married (72.15%), while 27.84% were unmarried. In terms of age distribution, most informants fell within the 50–75 years age group (31.64%), followed by those aged 36–50 years (30.37%). Informants aged 20–35 years and those above 75 each accounted for 18.98%, reflecting a significant contribution from both younger and elderly knowledge holders. Regarding educational background, 24.05% of respondents had no formal education, while 29.11% had received primary education. Other levels of education included middle school (12.65%), secondary education (15.18%), and higher secondary (12.65%), with only 6.32% having education beyond high school.

Medicinal plant diversity

A total of 133 medicinal plant species were documented in the study area, distributed across 58 families. The family Asteraceae emerged as the most dominant, contributing 12 species followed by Fabaceae (9 species), Lamiaceae (7 species), and both Apocynaceae and Solanaceae (6 species each). Families such as Amaranthaceae, Euphorbiaceae, Malvaceae, and Moraceae were each represented by 5 species. Mid-level representation was noted in families like Brassicaceae, Papaveraceae, Plantaginaceae, Poaceae, and Rosaceae, each with 3 species. Additionally, 14 families were represented by 2 species each, including Acanthaceae, Apiaceae, Boraginaceae, Phyllanthaceae, and Polygoniaceae, among others. Importantly, a significant number of families (33 in total) were monotypic, represented by a single species each. These include Asphodelaceae, Berberidaceae, Cannabinaceae, Combretaceae, Cucurbitaceae, Scrophulariaceae, Urticaceae, Zygophyllaceae, and others. The ethnomedicinal flora documented in the Samahni Valley exhibited considerable variation in growth forms. Among the 133 recorded species, herbs were overwhelmingly dominant, comprising 85 species of the total. Trees formed the second largest category, with 24 species. Shrubs accounted for 20 species. Less represented were ferns and climbers, with 3 species and 1 species, respectively (Fig. 2A).

Plant parts used for medicinal purposes

The ethnomedicinal data collected from the study area revealed a wide range of plant parts utilized in traditional healing practices (Fig. 2B). Among the 133 documented species, the whole plant was most frequently used, accounting for 51 species. Leaves were the second most commonly used plant part, recorded in 45 species. Fruits and seeds were also significant, cited in 18 and 17 species respectively. Other parts were used less frequently: flowers in 8 species, stems in 7, roots in 6, barks in 5, latex in 4, and rhizomes in only 3 species. The relatively lower use of subterranean parts (roots and rhizomes) and bark may reflect local conservation ethics or practical challenges in harvesting from woody perennials and slow-growing species.

Modes of preparation and administration

The ethnomedicinal practices in study area reflect a diverse set of traditional knowledge systems regarding the preparation and administration of plant-based remedies. Among the 133 documented medicinal plant species, infusion was the most prevalent method, employed in 50 instances. Paste applications were the second most common mode, observed in 29 species, predominantly used for topical treatments of skin ailments, wounds, and inflammations. Powdered formulations were recorded in 23 species (17.3%), commonly used for oral administration either alone or with food or honey. Other notable preparation modes included decoctions (23 species), extracts (11), poultices (7), and cooked preparations (5). Less commonly, plant parts were administered directly (6) or through chewing (2 species), typically in the case of fresh leaves or seeds for immediate relief, such as in dental or digestive issues.

Principal Component Analysis (PCA) was employed to explore patterns and relationships among different modes of medicinal plant preparation and administration based on their use across the 133 documented species (Fig. 3). The first two principal components (PC1 and PC2) explained 35.9% and 18.7% of the total variance, respectively, accounting for a combined 54.6% of the data variability. The PCA biplot revealed distinct grouping of species around key modes of administration. Infusion emerged as the most influential mode along PC1, with a dense cluster of species aligning positively along this axis. This reflects its dominant role as the preferred method. Similarly, paste, powder, and decoction showed moderate to strong associations with the principal axes, indicating their secondary but still significant contribution to traditional medicinal practices in the region. Chewing and direct application appeared on the far ends of the PCA space and were associated with relatively fewer species, confirming their more specialized and less common usage.

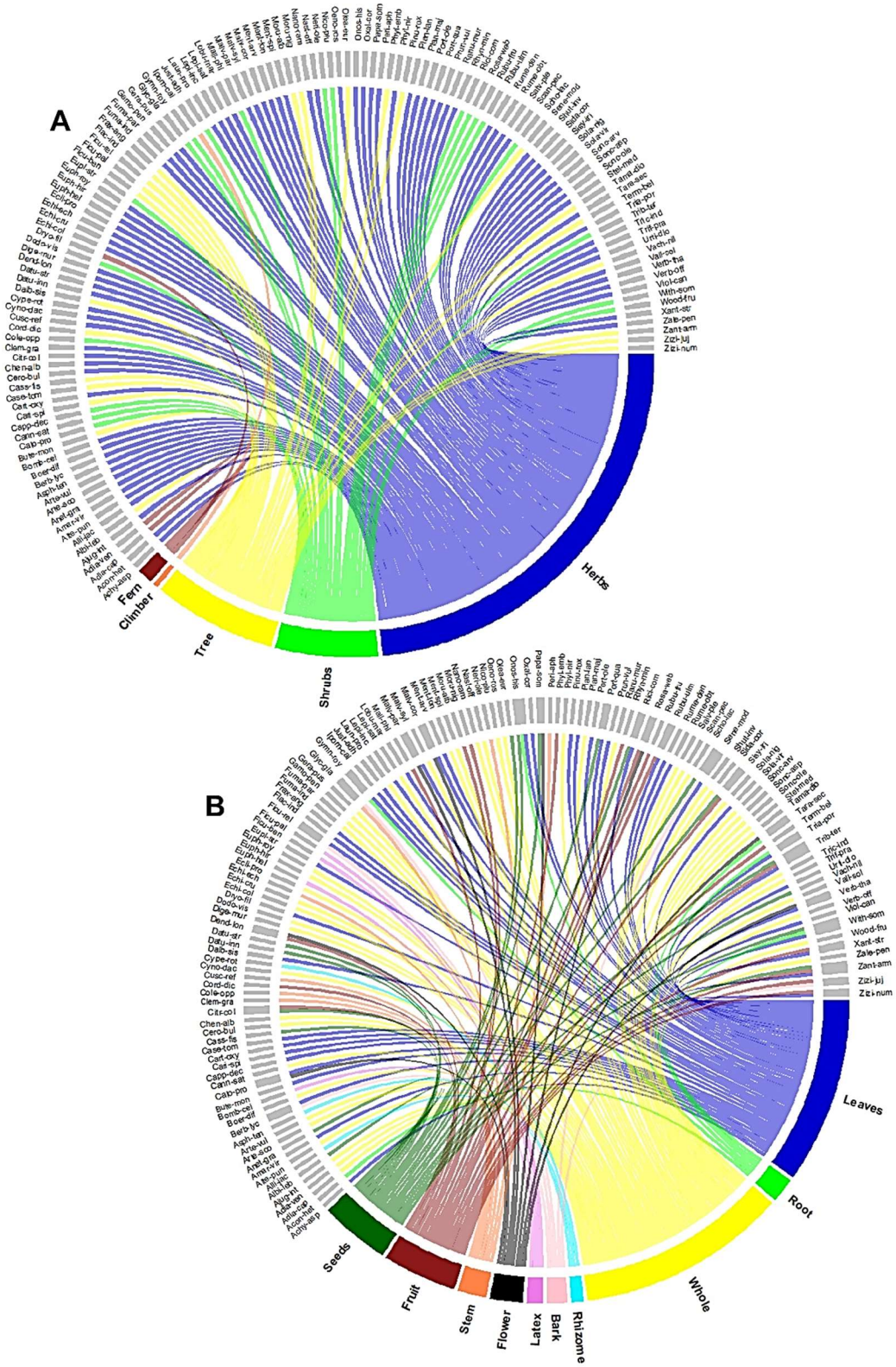

Fig. 2. Chord diagram illustrating the relationship between medicinal plant species and **A.** Their respective growth forms (Herbs, Shrubs, Trees, Climbers, and Ferns) recorded in the study area; and **B.** Their used parts in traditional healing practices.. The outer arcs represent individual plant species (abbreviated codes), while the inner colored sectors indicate their distribution across growth form categories. The width of each arc reflects the number of species associated with each category, showing the predominance of herbaceous taxa. For full species names corresponding to the abbreviated codes, refer to Supplementary Table S1.

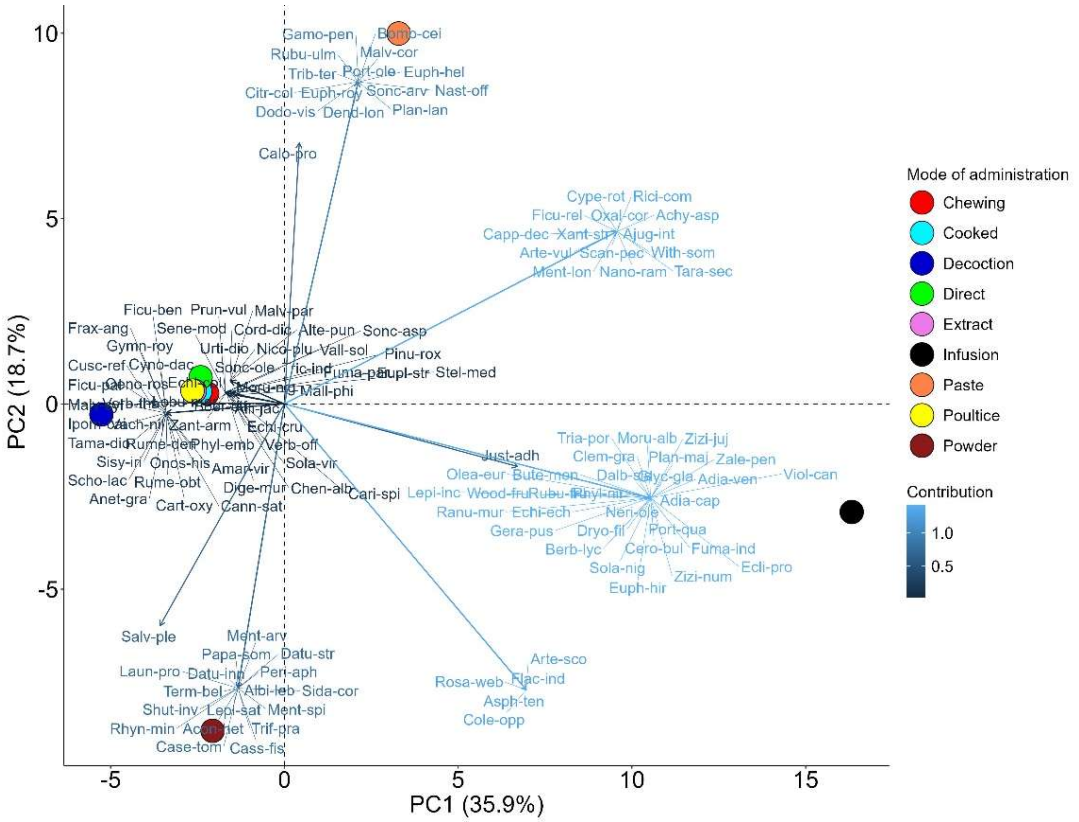

Fig. 3. Principal Component Analysis (PCA) biplot showing the relationship between medicinal plant species and their modes of preparation and administration in study area. Each color represents a distinct preparation method. The position of each species (abbreviated codes) relative to the axes indicates its contribution to variation across modes. For full species names and abbreviations, refer to Supplementary Table S1.

Extract, poultice, and cooked preparations showed scattered patterns, suggesting that their application is more species-specific rather than broadly distributed across taxa.

Therapeutic applications of medicinal plants

The ethnomedicinal flora of the Samahni Valley exhibited a wide range of therapeutic applications, highlighting the depth of indigenous knowledge and the community's strong reliance on traditional medicine. The documented species were used to treat 17 distinct disease categories, with many showing multi-purpose medicinal potential. Digestive disorders were the most commonly addressed ailment category, treated by 59 plant species. Although 59 plant species were reported for digestive disorders, the high ICF value (0.69) indicates that many informants consistently mentioned a smaller core group of highly valued species, demonstrating a strong cultural consensus despite the broader diversity of options. This dominance is consistent with rural health needs, where gastrointestinal issues are prevalent due to factors like contaminated water, poor sanitation, and food-related infections. Notable species for digestive ailments included *Zanthoxylum armatum* DC, *Chenopodium album* L, *Cordia dichotomya* G.Forst, and *Sonchus oleraceus* L. Respiratory problems were the second most frequent health issue treated (35 species), encompassing conditions like asthma, bronchitis, and coughs. Species such as *Mentha spicata* L, *Justicia adhatoda* L, and *Portulaca quadrifida* L were traditionally used in this regard. Liver disorders were treated with 28 species, with plants like *Ficus palmata* Forssk, *Mallotus philippensis* (Lam.) Müll.Arg, and *Ziziphus nummularia* (Burm.f.) Wight & Arn being most cited. Hypertension and pain relief were addressed by 27 species, and fevers were managed with 24 species, many of which overlapped in treating inflammatory and infectious conditions. Plants such as *Flacourtia indica* (Burm.f.) Merr, *Solanum nigrum* L., and *Papaver somniferum* L were commonly employed for fever and related symptoms. Kidney problems (23 species), inflammatory conditions (21), wound healing (18), and skeletal disorders (17) also featured prominently among the therapeutic uses. Skin diseases and diabetes were each treated by 13 species, indicating targeted ethnotherapeutic knowledge in dermatological and metabolic disorders. Meanwhile, sexual health issues (10 species), blood purification (11), eye infections (5), and hemorrhoids (5) were among the less commonly addressed but still significant health concerns. Many species displayed polytherapeutic

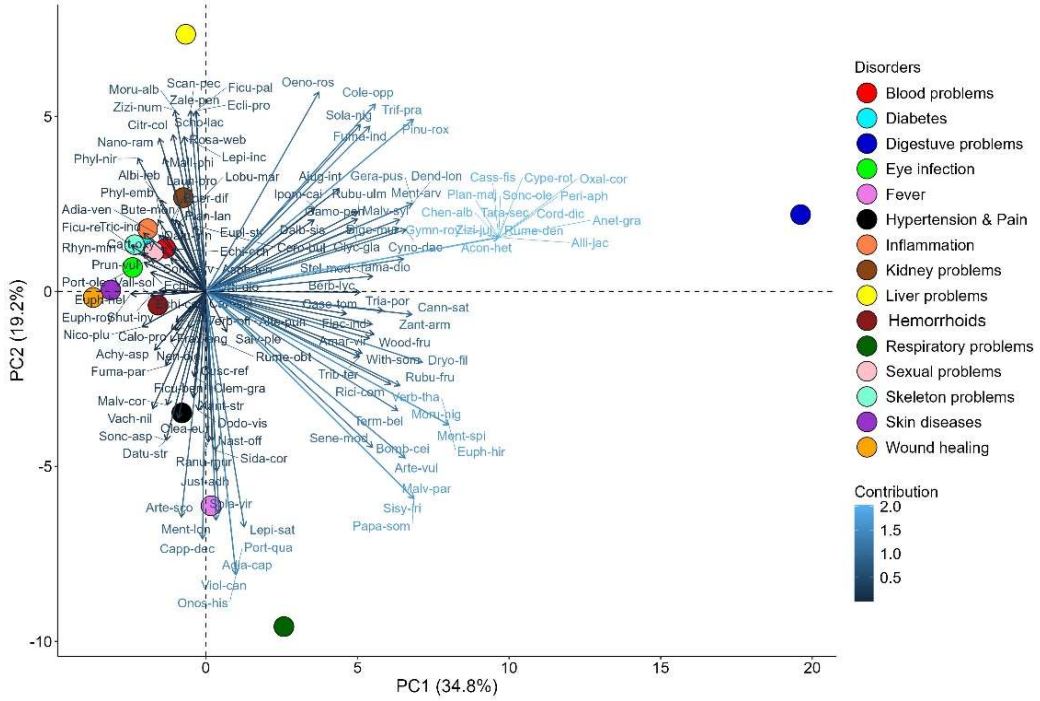

Fig. 4. PCA biplot displaying the association of medicinal plant species with their corresponding disease categories. Colored markers represent different disorders, and vector length indicates contribution strength. The spread reflects the specificity and multifunctionality of plant species in traditional healing. For full species names and abbreviations, refer to Supplementary Table S1.

applications. For instance, *Berberis lycium* Royle was used for ulcers, fever, jaundice, and hypertension, whereas *Withania somnifera* (L.) Dunal had applications in sexual disorders, inflammation, and bronchitis. Likewise, *Euphorbia hirta* L and *Cassia fistula* L were each linked to multiple categories such as skin diseases, asthma, and digestive issues.

The PCA ordination revealed distinct clustering of medicinal plant species based on their therapeutic uses, indicating patterns in traditional knowledge regarding disease-specific applications. The analysis explained a cumulative variance of 54% across the first two principal components, with PC1 (34.8%) and PC2 (19.2%), effectively distinguishing plant usage across the 17 disorder categories (Fig. 4). Clusters were observed around several major health concerns, including liver disorders, fever, respiratory ailments, and digestive conditions, suggesting concentrated ethnomedicinal reliance on specific species for these ailments. In contrast, plant species associated with sexual problems, eye infections, and hemorrhoids were more dispersed and isolated, reflecting specialized or less commonly reported uses.

Use value (uv) and frequency of citation (fc) analysis

The correlation between Use Value and Frequency of Citation revealed significant insights into the relative cultural and medicinal importance of documented plant species (Fig. 5). A strong positive linear relationship was observed, indicating that species cited more frequently by informants tend to have higher use values, thereby reflecting greater ethnomedicinal relevance. Several species stood out with exceptionally high UV and FC scores. *Citrullus colocynthis* (L.) Schrad (UV = 0.92, FC = 53), *Morus nigra* (UV = 0.91, FC = 37), *Datura innoxia* Mill (UV = 0.91, FC = 43), and *Ziziphus jujuba* Mill (UV = 0.96, FC = 51) were among the most culturally significant plants in the local pharmacopoeia (Supplementary Table S1**)**. These species are not only frequently mentioned but are also associated with a wide range of therapeutic uses. Other notable high-ranking species included *Rosa webbiana* Wall. ex Royle (UV = 0.97), *Rumex obtusifolius* L (UV = 0.90), and *Aconitum heterophyllum* Wall. ex Royle (UV = 0.90), despite moderate citation frequencies, reflecting their perceived efficacy and specialized applications. Conversely, species like *Nerium oleander* L (UV = 0.26, FC = 23) and *Terminalia bellirica* (Gaertn.) Roxb (UV = 0.28, FC = 21) had relatively lower use values despite being cited by a reasonable number of informants, possibly due to limited or highly specific uses, or lower accessibility and awareness.

Informant consensus factor and use report

Among the 15 therapeutic categories evaluated, hypertension and pain had the highest ICF (0.89), followed closely by diabetes (0.88) and blood problems (0.85), suggesting strong agreement among informants on the plants used for these conditions (Supplementary Table 1**)**. Skeleton problems (0.73), hemorrhoids (0.70), and digestive disorders (0.69) also showed relatively high

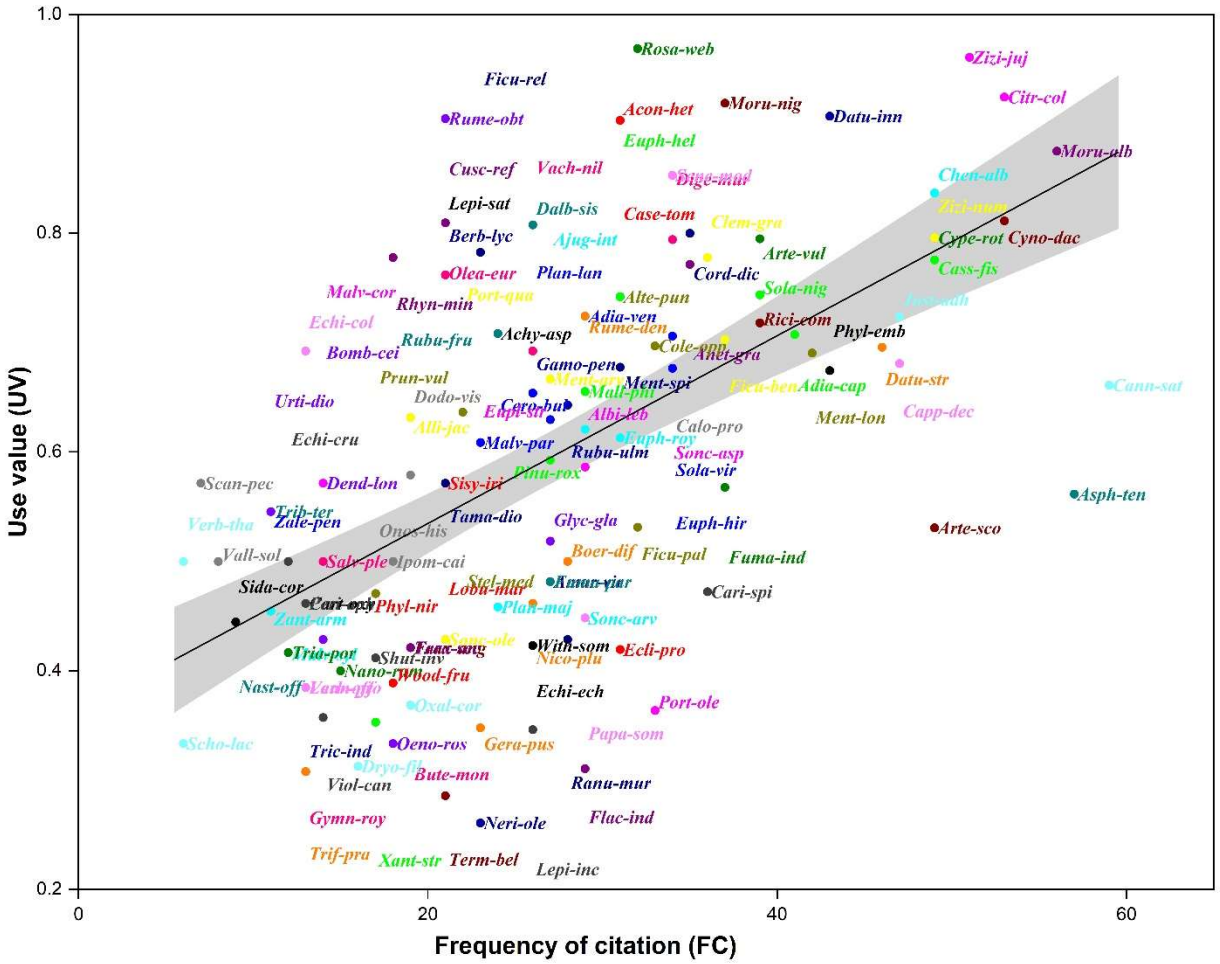

Fig. 5. Scatterplot showing the relationship between Use Value (UV) and Frequency of Citation (FC) for medicinal plant species used in the Samahni Valley. Each point represents a species (abbreviated name), with the regression line and confidence interval (shaded) indicating a positive correlation. For full species names and abbreviations, refer to Supplementary Table S1.

consensus, indicating that although these categories involve a wider range of taxa, the knowledge about their use remains well shared within the community. In contrast, categories like fever (0.40), skin diseases (0.50), and inflammation (0.55) had lower ICF values. The scatterplot (Fig. 6) supports these findings by plotting the number of taxa against the number of use reports. Categories such as digestive problems and diabetes stand out for both high use reports and high consensus, reinforcing their central role in the region's traditional healthcare system.

DISCUSSION

Although convenience sampling was used due to regional constraints, a higher number of older and married individuals participated in the study, which may have influenced the observed demographic trend. This aligns with similar findings from Uganda, India, and Northern Pakistan, where elders have been reported to hold the majority of traditional knowledge (Schultz *et al*., 2020; Waheed *et al*., 2023; Haq *et al*., 2024). These observations suggest that ethnobotanical knowledge is often concentrated among older generations, likely due to cumulative experience and oral transmission practices. Additionally, the relatively high proportion of informants with primary education or no formal schooling supports the idea that such knowledge is acquired through lived experience and intergenerational learning, rather than formal education (Inta *et al*., 2013; Sheng *et al*., 2024). Such dynamics have already been described at length in indigenous and borderland communities where customary medicine remains the first point of healthcare owing to a scarcity of biomedical facilities (Dahal 2022). In addition, women's active role, especially as healers and caretakers of households, maintains ethnobotanical literature focusing on women's centrality in controlling plant-based knowledge of health (Zaman *et al*., 2025; Gillani *et al*., 2024a). Though their work is so critical, women knowledge systems tend to be underrepresented because data gathering is often constrained by gender. Having both male and female informants included in this

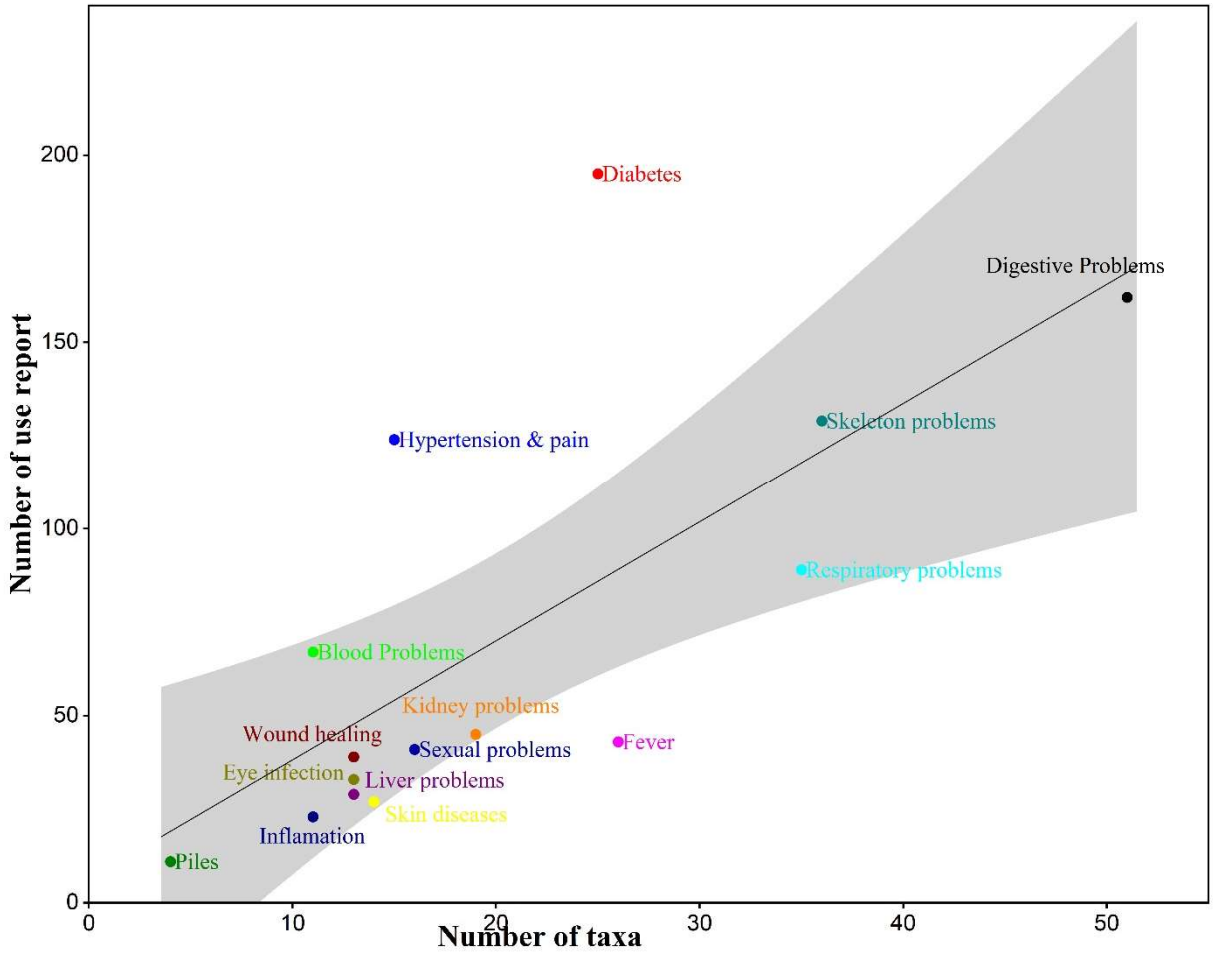

Fig. 6. Relationship between the number of taxa used and number of use reports for each disease category in Samahni Valley. The shaded area represents the confidence interval for the regression line. Categories above the line indicate higher-than-expected use intensity and informant agreement.

study gives a broader reflection of local knowledge and seeks to fill those missing gaps from history. The extent of cultural coherence revealed at the different age levels and educational strata further supports the integrality of medicinal plant knowledge in everyday life and the durability of such knowledge systems among marginalized populations (Arshad *et al*., 2020; Zank *et al*., 2022).

The extensive diversity of medicinal plants documented in the study area is a testament to both the ecological wealth of the transboundary landscape and the cultural continuity of ethnomedicinal practices among its people. This is consistent with earlier work in similarly biodiverse but marginal landscapes like Northern Pakistan, where wild plants remain central to community health systems (Rahman *et al*., 2022; Hussain *et al*., 2024; Muhammad *et al*., 2025). The dominance of herbs among the recorded growth forms is also to be expected based on experience elsewhere in the Himalayas and other subtropical regions where herbaceous species tend to be more available, easier to gather, and with a broader set of medicinal uses than either shrubs or trees. Dominance of Asteraceae, Fabaceae, and Lamiaceae families captures wider ethnobotanical trends because these families are universally known to have pharmacologically active molecules and are common in traditional medicine (Gras *et al*., 2021; Waheed *et al*., 2025). The use distribution of plant parts, particularly the reliance on leaves and certain whole herbaceous species, reflects both cultural preference and ecological awareness. In this context, the use of whole plants generally involves small, fast-regenerating herbs, rather than large or woody taxa, thereby minimizing ecological impact. Such selective and sustainable harvesting practices suggest the presence of a local conservation ethic, consistent with observations from other ethnobotanical studies (Constant and Tshisikhawe 2018; Al Muhdhar *et al*., 2019; Rodrigues *et al*., 2020). The dominance of herbaceous taxa, frequent use of leaves and easily regenerating whole herbs, and preference for infusion-based remedies reflect eco-conscious and sustainable resource-use practices among the local healers (Al Muhdhar *et al*., 2019; Wu *et al*., 2023). The diversity of species and range of medicinal

applications documented in this study confirm the complexity of traditional medical systems and underscore the imperative to retain this knowledge in the face of modernization and environmental decay (Zaman *et al*., 2025).

The medicinal uses of the documented plants provide valuable insights into community health concerns and traditional ethnomedical knowledge. The dominance of species used for gastrointestinal, respiratory, and hepatic disorders closely reflects the epidemiological profile of rural border communities, where water-borne diseases and inadequate sanitation are prevalent (Boafo *et al*., 2024; Ralte and Singh 2024). High informant agreement and the widespread use of infusions reflect a well-adapted, low-cost traditional healthcare system aligned with local needs. There are similar trends in conventional traditional medicine in the Western Himalayas and Ethiopia, where decoction and infusion predominate as preparation approaches because they are easy to use and effective (Manzoor *et al*., 2023; Derso *et al*., 2024). The multi-functionality of several species also suggests an integrative method of healing, in which plants are selected not merely for discrete symptoms but for syndromic uses more generally, e.g., the treatment of fever in combination with inflammation or respiratory difficulty. This multi-functionality enriches local pharmacopoeias and underscores the sophistication of indigenous classification systems, which may be different from biomedical ones but are no less refined (Sõukand *et al*., 2017; Pietersen *et al*., 2018). The low frequency of use of some preparation modes, for example, chewing or direct application, indicates either species-specific use or practices reserved for acute needs (Cunningham *et al*., 2012; Mirzaman *et al*., 2023).

High-ranked species like *Citrullus colocynthis*, *Morus nigra*, and *Datura innoxia* have proved to be in high demand in other regions' research, which depicts their extensive range of pharmacological renown and simple availability (Mahmood *et al*., 2013; Tariq *et al*., 2014; Umair *et al*., 2019; Zareef *et al*., 2023; Khanum *et al*., 2024). The strong correlation of frequency of citation with use value supports that multiple validation and social dependence are chief drivers in shaping the perceived effectiveness of drugs (Byrne *et al*., 2019). Low-cited but highly used plants such as *Rosa webbiana* have specialist or context-dependent use that may not be extremely prevalent in practice but is highly valued within one home or system of healers (Khanum *et al*., 2024). This highlights the importance of balancing ethnographic nuance with quantitative indicators in appreciating the cultural role of medicinal plants (Leonti 2011; Hassan *et al*., 2023). Specifically, some taxa with low use value but frequent citations can signify declining use, reduced availability, or shifting palates within the community (Smith-Hall 2012). This may be a sign of ongoing changes in local knowledge systems, possibly due to resource depletion or intergenerational discontinuity (Zank *et al*., 2022). The multi-use nature of certain high-valued species highlights their central role in the indigenous medicinal system and suggests that they would be most vulnerable to over-exploitation in the absence of conservation (Hamilton, 2011). This evidence is congruent with international research highlighting the primacy of cultural significance for conservation planning, where high-value species tend to be most at risk of being exploited (Gregory and Trousdale 2009; Haq *et al*., 2024). Incorporating these regionally important species into conservation and cultivation programs would assist in maintaining both biodiversity as well as local healthcare traditions (Kumar *et al*., 2021). In addition to their cultural significance, many documented species face increasing ecological pressures due to habitat degradation, overharvesting, and climate variability. Notably, species such as Berberis lycium and Aconitum heterophyllum are either endemic or listed as vulnerable according to the IUCN Red List (Haq *et al*., 2022; Shaheen *et al*., 2023). These findings are consistent with the recent study by Khanum *et al*., (2024) from the adjacent Sanghar Mountains of District Bhimber, which also reported similar threats to wild medicinal flora and emphasized the importance of community-based resource management. However, unlike the Sanghar study, our results reveal stronger evidence of local conservation awareness through the selective use of aerial parts and reduced reliance on roots, indicating an indigenous conservation ethic shaped by both ecological sensitivity and livelihood dependency (Arshad *et al*., 2024).

The vitality of border communities' indigenous knowledge persists in the face of ongoing political, ecological, and socio-economic pressures (Kohsaka and Rogel 2021). Parallel to this, are pressing conservation needs, particularly for species threatened with overhunting or diminishing populations. Low informant consensus for diseases such as dermatoses indicates fragmented knowledge or limited treatment options, while the low use of roots and rhizomes suggests a local norm of sustainable harvesting (Zhao *et al*., 2023). Yet, official conservation measures are lacking to protect this diversified ethnobotanical heritage. This aligns with international calls for mainstreaming local knowledge bearers towards managing biodiversity and prioritizing transboundary cooperation for safeguarding shared ecological as well as cultural resources (Petursson *et al*., 2011). Holistic and community-based conservation strategies must be followed to address these issues. High-priority species like *Citrullus colocynthis, Ziziphus jujuba*, and *Datura innoxia* that showed cultural value and multiple medicinal values must be prioritized for both ex-situ and in situ conservation. Regulated harvesting culture-based community-managed conservation areas can ensure the sustainability of wild populations and maintain traditional practice (Kothari *et al*., 2013). At the

same time, encouraging people to cultivate useful species such as *Mentha longifolia* and *Berberis lycium* at home or in agroforestry systems can relieve pressure on wild populations and increase local healthcare resilience. Policy frameworks need to formally recognize indigenous medical systems, integrating them into conservation and health planning to ensure that local communities are empowered stakeholders in the management of their biocultural heritage.

CONCLUSION

This study presents one of the first comprehensive ethnobotanical investigations from the Samahni Valley, a politically sensitive and under documented transboundary region along the Indo-Pak border. It highlights a rich diversity of 133 wild medicinal plant species and underscores the critical role of traditional knowledge systems among marginalized communities who rely heavily on natural resources for primary healthcare. The dominance of herbaceous taxa, frequent use of leaves and whole plants, and preference for infusion-based remedies reflect eco-friendly, low-cost, and culturally embedded healing practices. Quantitative measures for gastrointestinal, respiratory, and hepatic disorders indicate strong community-level validation and accumulated experiential learning over generations. To strengthen conservation outcomes, we recommend promoting the local cultivation of high-demand medicinal species such as *Mentha longifolia* (L.) L and *Berberis lycium* Royle to reduce pressure on wild populations. Moreover, integrating indigenous knowledge systems into regional conservation policies can enhance both biodiversity protection and healthcare resilience among marginalized communities. These findings highlight the need to conserve medicinal plant knowledge and resources by documentation, local involvement, and incorporation into conservation planning, especially in ecologically and politically fragile areas.

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LITERATURE CITED

Abdallah, E.M., Alhatlani, B.Y., de Paula Menezes, R., Martins, C.H.G. 2023 Back to nature: Medicinal plants as promising sources for antibacterial drugs in the post-antibiotic era. Plants **12(17)**: 3077.

Al Muhdhar, M.H.I., Rohman, F., Tamalene, M.N., Nadra, W.S., Daud, A., Irsyadi, H. 2019 Local wisdom-based conservation ethics of Tabaru traditional community on Halmahera Island, Indonesia. Int. J. Conserv. Sci. **10(3)**: .533–542.

Albuquerque, U.P., Lucena, R.F., Monteiro, J.M., Florentino, A.T., Almeida, C.D.F.C. 2006 Evaluating two quantitative ethnobotanical techniques. Ethnobot. Res. Appl. **4:** 51–60.

Arshad, F., Haq, S.M., Waheed, M., Jameel, M.A., Bussmann, R.W. 2024 Environmental variables drive medicinal plant composition and distribution in various forest types of subtropical region in Pakistan. Ecol. Front. **44(2)**: 234–246.

Arshad, F., Waheed, M., Iqbal, M., Fatima, K., Fatima, K. 2020 Ethnobotanical assessment of woody flora of district Kasur (Punjab), Pakistan. Ethnobot. Res. Appl. **20**: 1–13.

Boafo, Y.A., Ohemeng, F.N., Ayivor, J., Ayitiah, J.A., Yirenya-Tawiah, D., Mensah, A., Datsa, C., Annang, T.Y., Adom, L. 2024 Unraveling diarrheal disease knowledge, understanding, and management practices among climate change vulnerable coastal communities in Ghana. Front. Public Health **12**: 1352275.

Byrne, M.K., Miellet, S., McGlinn, A., Fish, J., Meedya, S., Reynolds, N., Van Oijen, A.M. 2019 The drivers of antibiotic use and misuse: the development and investigation of a theory driven community measure. BMC Public Health **19**: 1425.

Constant, N.L., Tshisikhawe, M.P. 2018 Hierarchies of knowledge: ethnobotanical knowledge, practices and beliefs of the Vhavenda in South Africa for biodiversity conservation. J. Ethnobiol. Ethnomed. **14**: 1–28.

Coombs, N.C., Campbell, D.G., Caringi, J. 2022 A qualitative study of rural healthcare providers' views of social, cultural, and programmatic barriers to healthcare access. BMC Health Serv. Res. **22**(1): 438.

Cunningham, A.B., Shanley, P., Laird, S.A. 2012 Health, habitats and medicinal plant use. In Colfer, C.J.P. (ed.). Human Health and Forests: a global overview of issues, practice and policy. Human health and forests: a global overview of issues, practice and policy. 35–62pp. London, UK, Earthscan.

Dahal, K.B. 2022 Engrained with modernity: commodification, medicalisation, and cross-border medical travel for health care in Nepal. Humanit. Soc. Sci. Commun. **9(1)**: 1–9.

Derso, Y.D., Kassaye, M., Fassil, A., Derebe, B., Nigatu, A., Ayene, F., Tamer, M., Van Damme, P. 2024 Composition, medicinal values, and threats of plants used in indigenous medicine in Jawi District, Ethiopia: implications for conservation and sustainable use. Sci. Rep. **14(1)**: 23638.

Du, C., Bai, X., Li, Y., Tan, Q., Zhao, C., Luo, G., Wang, J., Wu, L., Li, C., Li, J., Xie, Y., Ran, C., Zhang, S., Xiong, L., Yuang, X., Liao, J., Dai, L., Long, M., Li, Z., Xue, Y., Zhang, X., Luo, Q., Shen, X., Yang, S., Li, M. 2024 The restoration of karst rocky desertification has enhanced the carbon sequestration capacity of the ecosystem in southern China. Glob. Planet. Change **243**: 104602.

El-Ramady, H., Hajdú, P., Törős, G., Badgar, K., Llanaj, X., Kiss, A., Abdalla, N., Omara, A.E.D., Elsakhawy, T., Elbasiouny, H., Elbehiry, F., Amer, M., El-Mahrouk, M.E., Prokisch, J. 2022 Plant nutrition for human health: a pictorial review on plant bioactive compounds for sustainable agriculture. Sustainability **14(14)**: 8329.

Eshete, M.A., Molla, E.L. 2021 Cultural significance of medicinal plants in healing human ailments among Guji semi-pastoralist people, Suro Barguda District, Ethiopia. J. Ethnobiol. Ethnomed. **17**: 1–18.

Fajinmi, O.O., Olarewaju, O.O., Van Staden, J. 2023 Propagation of medicinal plants for sustainable livelihoods, economic development, and biodiversity conservation in South Africa. Plants **12(5)**: 1174.

Fontana, N.M., Pasailiuk, M.V., Pohribnyi, O. 2022 Traditional ecological knowledge to traditional foods: the path to maintaining food sovereignty in Hutsulshchyna. Front. Sustain. Food Syst. **6**: 720757.

Gillani, S.W., Ahmad, M., Manzoor, M., Waheed, M., Iqbal, Z., Ullah, R., Pieroni, A., Zhang, L., Sulaiman, N., Alrhmoun, M. 2024 The nexus between ecology of foraging and food security: cross-cultural perceptions of wild food plants in Kashmir Himalaya. J. Ethnobiol. Ethnomed. **20(1)**: 77.

Gillani, S.W., Ahmad, M., Zafar, M., Haq, S.M., Waheed, M., Manzoor, M., Shaheen, H., Sultana, S., Rehman, F.U., Makhkamov, T. 2024a An insight into indigenous ethnobotanical knowledge of medicinal and aromatic plants from Kashmir Himalayan region. Ethnobot. Res. Appl. **28**: 1–21.

Gizaw, Z., Astale, T., Kassie, G.M. 2022 What improves access to primary healthcare services in rural communities? A systematic review. BMC Prim. Care **23(1)**: 313.

Gras, A., Hidalgo, O., D'Ambrosio, U., Parada, M., Garnatje, T., Valles, J. 2021 The role of botanical families in medicinal ethnobotany: a phylogenetic perspective. Plants **10(1)**: 163.

Gregory, R., Trousdale, W. 2009 Compensating aboriginal cultural losses: an alternative approach to assessing environmental damages. J. Environ. Manage. **90(8)**: 2469–2479.

Gong, H., Tan, X., Hou, J., Gong, Z., Qin, X., Nie, J., Zhu, H., Zhong, S. 2024 Separation, purification, structure characterization, and immune activity of a polysaccharide from Alocasia cucullata obtained by freeze-thaw treatment. Int. J. Biol. Macromol. **282**: 137232.

Guo, P., Zeng, M., Liu, M., Zhang, Y., Jia, J., Zhang, Z., Liang, S., Zheng, X., Feng, W. 2025 Zingibroside R1 isolated from Achyranthes bidentata Blume ameliorates LPS/D-GalN-induced liver injury by regulating succinic acid metabolism via the gut microbiota. Phytother. Res. **39(10)**: 4520–4534.

Gu, Z., Gu, L., Eils, R., Schlesner, M., Brors, B. 2014 Circlize implements and enhances circular visualization in R. Bioinformatics **30(19)**: 2811–2812.

Hamilton, A.C. 2004 Medicinal plants, conservation and livelihoods. Biodivers. Conserv. **13(8)**: 1477–1517.

Haq, S.M., Khoja, A.A., Waheed, M., Pieroni, A., Siddiqui, M.H., Bussmann, R.W. 2024 Plant cultural indicators of forest resources from the Himalayan high mountains: implications for improving agricultural resilience, subsistence, and forest restoration. J. Ethnobiol. Ethnomed. **20(1)**: 44.

Haq, S.M., Waheed, M., Khoja, A.A., Amjad, M.S., Bussmann, R.W., Ali, K. 2023 A cross-cultural study of high-altitude botanical resources among diverse ethnic groups in Kashmir Himalaya, India. J. Ethnobiol. Ethnomed. **19(1)**: 12.

Haq, S.M., Yaqoob, U., Majeed, M., Amjad, M.S., Hassan, M., Ahmad, R., Waheed, M., Bussmann, R.W., Calixto, E.S., Proćków, J., De la Lastra, J.M.P. Morales-de la Nuez, A. 2022 Quantitative ethnoveterinary study on plant resource utilization by indigenous communities in high-altitude regions. Front. Vet. Sci. **9**: 944046.

Haq, S.M., Khoja, A.A., Waheed, M., Siddiqui, M.H., Alamri, S., Alfagham, A.T., Al-Humaid, L.A., Bussmann, R.W. 2024a Food ethnobotany of forest resource in the high-altitude Himalaya Mountains: enhancing the food sovereignty of ethnic groups. For. Policy Econ. **164**: 103247.

Haq, S.M., Khoja, A.A., Lone, F.A., Waheed, M., Bussmann, R.W., Casini, R., Mahmoud, E.A., Elansary, H.O. 2023a Keeping healthy in your skin—plants and fungi used by indigenous Himalayan communities to treat dermatological ailments. Plants **12(7)**: 1575.

Hassan, M., Abdullah, A., Haq, S.M., Yaqoob, U., Bussmann, R.W., Waheed, M. 2023 Cross-ethnic use of ethnoveterinary medicine in the Kashmir Himalaya—a northwestern Himalayan region. Acta Ecol. Sin. **43(4)**: 617–627.

Heinrich, M., Edwards, S., Moerman, D.E., Leonti, M. 2009 Ethnopharmacological field studies: a critical assessment of their conceptual basis and methods. J. Ethnopharmacol. 124(1): 1–17.

Hussain, M., Alam, J., Shah, G.M., Gul, A., Majid, A., Shafqat, N., Khan, S.M.R. 2024 Assessment of traditional knowledge of medicinal plants practiced by rural communities residing around Musk Deer National Park, Kashmir Himalaya, Pakistan. Ethnobot. Res. Appl. **28**: 1–23.

Inta, A., Trisonthi, P., Trisonthi, C. 2013 Analysis of traditional knowledge in medicinal plants used by Yuan in Thailand. J. Ethnopharmacol. **149(1):** 344–351.

Jabeen, S., Arshad, F., Harun, N., Waheed, M., Alamri, S., Haq, S.M., Vitasović-Kosić, I., Fatima, K., Chaudhry, A.S., Bussmann, R.W. 2024 Folk knowledge and perceptions about the use of wild fruits and vegetables—cross-cultural knowledge in the Pipli Pahar reserved forest of Okara, Pakistan. Plants **13(6)**: 832.

Kassambara, A., Mundt, F. 2017 Package 'factoextra': extract and visualize the results of multivariate data analyses. Software **76(2)**: 10–18637.

Khanum, H., Ishtiaq, M., Maqbool, M., Hussain, I., Bhatti, K.H., Mazhar, M.W., Gul, A. 2024 Evaluating the conservation value and medicinal potential of wild herbaceous flora in the Sanghar Mountains of District Bhimber, AJK, Pakistan. Ethnobot. Res. Appl. **27**: 1–41.

Khoja, A.A., Waheed, M., Haq, S.M., Bussmann, R.W. 2024 The role of plants in traditional medicine and current therapy: a case study from North part of Kashmir Himalaya. Ethnobot. Res. Appl. **27**: 1–23.

Kohsaka, R., Rogel, M. 2021 Traditional and local knowledge for sustainable development: empowering the indigenous and local communities of the world. In: Leal Filho, W., Marisa Azul, A., Brandli, L., Lange Salvia, A., Wall, T. (eds) Partnerships for the Goals. 1261–1273pp. Encyclopedia of the UN Sustainable Development Goals. Springer, Cham.

Kothari, A., Camill, P., Brown, J. 2013 Conservation as if people also mattered: policy and practice of community-based conservation. Conserv. Soc. **11(1)**: 1–15.

Krigas, N., Karapatzak, E., Panagiotidou, M., Sarropoulou, V., Samartza, I., Karydas, A., Damianidis, C.K., Najdovski, B., Teofilovski, A., Mandzukovski, D., Stipanović, V.B., Papanastasi, K., Kapagianni, P.D., Fotakis, D., Grigoriadou, K., Tsoktouridis, G., Andonovski, V., Maloupa, E. 2022 Prioritizing plants around the cross-border area of Greece and the Republic of

North Macedonia: integrated conservation actions and sustainable exploitation potential. Diversity **14(7):** 570.

Kumar, A., Kumar, S., Komal, Ramchiary, N., Singh, P. 2021 Role of traditional ethnobotanical knowledge and indigenous communities in achieving sustainable development goals. Sustainability **13(6)**: 3062.

Leonti, M. 2011 The future is written: impact of scripts on cognition, selection, knowledge and transmission of medicinal plant use and its implications for ethnobotany and ethnopharmacology. J. Ethnopharmacol. **134(3)**: 542–555.

Liu, X., Li, S., Feng, Y., Chen, X., Ma, Y., Xiao, H., Zhao, Y., Liu, S., Zheng, G., Yang, X., Wu, F., Xie, J. 2024 Traditional knowledge of animal-derived medicines used by Gelao community in Northern Guizhou, China. J. Ethnobiol. Ethnomed. **20(1)**: 31.

Lou, Y., Zou, X., Pan, Z., Huang, Z., Zheng, S., Zheng, X., Yang, X., Bao, M., Zhang, Y., Gu, J., Zhang, Y. 2024 The mechanism of action of Botrychium (Thunb.) Sw. for prevention of idiopathic pulmonary fibrosis based on 1H-NMR-based metabolomics. J. Pharm. Pharmacol. **76(8)**: 1018–1027.

Luo, P., Feng, X., Liu, S., Jiang, Y. 2024 Traditional uses, phytochemistry, pharmacology and toxicology of Ruta graveolens L.: a critical review and future perspectives. Drug Des. Dev. Ther. **18**: 6459–6485.

Mahmood, A., Mahmood, A., Malik, R.N., Shinwari, Z.K. 2013 Indigenous knowledge of medicinal plants from Gujranwala District, Pakistan. J. Ethnopharmacol. **148(2)**: 714–723.

Manzoor, M., Ahmad, M., Zafar, M., Haq, S.M., Shaheen, H., Waheed, M., Gillani, S.W., Sultana, S., Makhkamov, T. 2023 Unveiling the indigenous ethnomedicinal knowledge of genus Nepeta from Division Muzaffarabad, Azad Jammu & Kashmir, Pakistan. Ethnobot. Res. Appl. **26:** 1–15.

Marques, B., Freeman, C., Carter, L. 2021 Adapting traditional healing values and beliefs into therapeutic cultural environments for health and well-being. Int. J. Environ. Res. Public Health **19(1)**: 426.

Mattalia, G., Stryamets, N., Grygorovych, A., Pieroni, A., Sõukand, R. 2021 Borders as crossroads: the diverging routes of herbal knowledge of Romanians living on the Romanian and Ukrainian sides of Bukovina. Front. Pharmacol. **11**: 598390.

Muhammad, M., Waheed, A., Wahab, A., Ameen, N., Ullah, I., Majeed, M., Waheed, M., Hakeem, K.R., Dawood, M.F., Li, W.J. 2025 Quantitative exploration and conservation of the medicinal plant resources used by the inhabitants of Northern Pakistan. Genet. Resour. Crop Evol. **72**: 7859–7891.

Mirzaman, Z., Kayani, S., Manzoor, M., Jameel, M.A., Waheed, M., Gillani, S.W., Babar, C.M., Bussmann, R.W. 2023 Ethnobotanical study of Makra Hills District Muzaffarabad, Azad Jammu and Kashmir, Pakistan. Ethnobot. Res. Appl. **26**: 1–17.

Nolan, J.M., Turner, N.J. 2011 Ethnobotany: the study of people-plant relationships. Ethnobiol. **9**: 133–147.

Paasi, A. 2022 Examining the persistence of bounded spaces: remarks on regions, territories, and the practices of bordering. Geogr. Ann. Ser. B Hum. Geogr. 104(1): 9–26.

Petursson, J.G., Vedeld, P., Kaboggoza, J. 2011 Transboundary biodiversity management: institutions, local stakeholders, and protected areas: a case study from Mt. Elgon, Uganda and Kenya. Soc. Nat. Resour. 24(12): 1304–1321.

Pietersen, S., López-Acosta, J.C., Gomez-Díaz, J.A., Lascurain-Rangel, M. 2018 Floristic diversity and cultural importance in agroforestry systems on small-scale farmer's livelihoods in Central Veracruz, México. Sustainability **10(1)**: 279.

Rahman, Q., Nadeem, M.S., Umair, M., Altaf, M., Ni, J., Abbasi, A.M., Jameel, M.A., Pieroni, A., Hamed, M.H., Ashraf, S., Sadaf, T. 2022 Medicinal waterbirds in the traditional healthcare system: an assessment of biodiversity–cultural linkages in Eastern Khyber Pakhtunkhwa, Pakistan. J. Ethnobiol. Ethnomed. **18(1)**: 57.

R Core Team 2022 R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Ralte, L., Singh, Y.T. 2024 Ethnobotanical survey of medicinal plants used by various ethnic tribes of Mizoram, India. PLoS One **19(5)**: e0302792.

Ribeiro, R.V., Bieski, I.G.C., Balogun, S.O., de Oliveira Martins, D.T. 2017 Ethnobotanical study of medicinal plants used by Ribeirinhos in the North Araguaia microregion, Mato Grosso, Brazil. J. Ethnopharmacol. **205**: 69–102.

Rodrigues, E., Cassas, F., Conde, B.E., Da Cruz, C., Barretto, E.H.P., Dos Santos, G., Figueira, G.M., Passero, L.F.D., Dos Santos, M.A., Gomes, M.A.S., Matta, P., Yazbek, P., Garcia, R.J.F., Braga, S., Aragaki, S., Honda, S., Sauini, T., da Fonseca-Kruel, V.S., Ticktin, T. 2020 Participatory ethnobotany and conservation: a methodological case study conducted with quilombola communities in Brazil's Atlantic Forest. J. Ethnobiol. Ethnomed. **16**: 2.

Shaheen, H., Aziz, S., Nasar, S., Waheed, M., Manzoor, M., Siddiqui, M.H., Alamri, S., Haq, S.M., Bussmann, R.W. 2023 Distribution patterns of alpine flora for long-term monitoring of global change along a wide elevational gradient in the Western Himalayas. Glob. Ecol. Conserv. **48**: e02702.

Scherrer, M.M., Zerbe, S., Petelka, J., Säumel, I. 2023 Understanding old herbal secrets: the renaissance of traditional medicinal plants beyond the twenty classic species? Front. Pharmacol. 14: 1141044.

Schultz, F., Anywar, G., Wack, B., Quave, C.L., Garbe, L.A. 2020 Ethnobotanical study of selected medicinal plants traditionally used in the rural Greater Mpigi region of Uganda. J. Ethnopharmacol. **256**: 112742.

Sharma, P.K., Singh, A., Sharma, N.K. 2022 A socio-ecological critique on India's local health traditions amidst rising incidence of global pandemics. J. Herb. Med. **34**: 100578.

Sheng, Y., Wang, J., Liu, S., Jiang, Y. 2024 IMN4NPD: an integrated molecular networking workflow for natural product dereplication. Anal. Chem. **96(7)**: 2990–2997.

Smith-Hall, C., Larsen, H.O., Pouliot, M. 2012 People, plants and health: a conceptual framework for assessing changes in medicinal plant consumption. J. Ethnobiol. Ethnomed. **8**: 1–11.

Sõukand, R., Hrynevich, Y., Vasilyeva, I., Prakofjewa, J., Vnukovich, Y., Paciupa, J., Hlushko, A., Knureva, Y., Litvinava, Y., Vyskvarka, S., Silivonchyk, H., Paulava, A., Kõiva, M., Kalle, R. 2017 Multi-functionality of the few: current and past uses of wild plants for food and healing in Liubań region, Belarus. J. Ethnobiol. Ethnomed. **13**: 1–42.

Ssenku, J.E., Okurut, S.A., Namuli, A., Kudamba, A., Tugume, P., Matovu, P., Wasige, G., Kafeero, H.M., Walusansa, A. 2022 Medicinal plant use, conservation, and the associated traditional knowledge in rural communities in Eastern Uganda. Trop. Med. Health **50(1):** 39.

Tariq, A., Mussarat, S., Adnan, M., AbdElsalam, N.M., Ullah, R., Khan, A.L. 2014 Ethnoveterinary study of medicinal plants in a tribal society of Sulaiman Range. Sci. World J. **2014(1)**: 127526.

Trotter, R.T., Logan, M.H. 2019 Informant consensus: a new approach for identifying potentially effective medicinal plants. In Etkin, N.L. (ed.) Plants and Indigenous Medicine and Diet 91–112pp. Routledge.

Tugume, P., Kakudidi, E.K., Buyinza, M., Namaalwa, J., Kamatenesi, M., Mucunguzi, P., Kalema, J. 2016 Ethnobotanical survey of medicinal plant species used by communities around Mabira Central Forest Reserve, Uganda. J. Ethnobiol. Ethnomed. **12**: 5.

Umair, M., Altaf, M., Bussmann, R.W., Abbasi, A.M. 2019 Ethnomedicinal uses of the local flora in Chenab riverine area, Punjab Province, Pakistan. J. Ethnobiol. Ethnomed. **15**: 7.

Ungar, M., Seymour, A. 2024 Access without borders: a scoping review to identify solutions to creating portable identity, education and health records for refugee children. J. Int. Migr. Integr. **25(4)**: 1989–2017.

Waheed, M., Haq, S.M., Jameel, M.A., Arshad, F., Bussmann, R.W. 2023 Documentation of ethnomedicinal plants used by the people living in reserved forests of semi-arid region Punjab, Pakistan. Ethnobot. Res. Appl. **26**: 1–17.

Waheed, M., Haq, S.M., Arshad, F., Bussmann, R.W., Pieroni, A., Mahmoud, E.A., Casini, R., Yessoufou, K., Elansary, H.O. 2023a Traditional wild food plants gathered by ethnic groups living in semi-arid region of Punjab, Pakistan. Biology **12(2)**: 269.

Waheed, M., Arshad, F., Muhammad, M., Hashem, A., Alnafissa, M., Abd-Allah, E.F., Sapayev, V. 2025 Food security and economic resilience of wild snake gourd (Trichosanthes cucumerina subsp. cucumerina) under different host trees in subtropical managed forests. Agrofor. Syst. **99(5)**: 97.

Wu, R.R., Li, X., Cao, Y.H., Peng, X., Liu, G.F., Liu, Z.K., Yang, Z., Liu, Z.Y., Wu, Y. 2023 China medicinal plants of the Ampelopsis grossedentata—a review of their botanical characteristics, use, phytochemistry, active pharmacological components, and toxicology. Molecules **28(20)**: 7145.

Yang, G., Qiu, H., Wang, N., Yang, D., Liu, Y. 2025 Tracking 35-year dynamics of retrogressive thaw slumps across permafrost regions of the Tibetan Plateau. Remote Sens. Environ. 325: 114786.

Zaman, W., Ayaz, A., Park, S. 2025 Climate change and medicinal plant biodiversity: conservation strategies for sustainable use and genetic resource preservation. Genet. Resour. Crop Evol. **72**: 1–34.

Zank, S., Júnior, W.S.F., Hanazaki, N., Kujawska, M., Ladio, A.H., Santos, M.L.M., Blanco, G.D., do Nascimento, A.L.B. 2022 Local ecological knowledge and resilience of ethnomedical systems in a changing world—South American perspectives. Environ. Sci. Policy **135**: 117–127.

Zareef, H., Gul, M.T., Qureshi, R., Aati, H., Munazir, M. 2023 Application of ethnobotanical indices to document the use of plants in traditional medicines in Rawalpindi District, Punjab, Pakistan. Ethnobot. Res. Appl. **25**: 1–29.

Zhao, J., Fan, L., Hu, S., Poha, Jiayangji, Wan, A.K.Y., Zeng, Y., Yang, Y., Duan, B., Lee, T.M. 2023 Understanding indigenous people's traditional Chinese medicinal plant harvesting preferences to guide sustainable management. People Nat. **5(4):** 1174–1186.

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