Quantitative study of the indian ethnobotanical medicinal plant resources in the remote Zanskar Valley of Ladakh

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Research

Abstract

Background: The urgent need for ethnobotanical studies arises from the critical role they play in preserving indigenous knowledge and native biodiversity, which are crucial for sustainable development and the conservation of medicinal plants in a rapidly changing environment. This study explores the ethnomedicinal knowledge of indigenous communities in the remote Zanskar Valley of Ladakh (India), specifically examining the medicinal plant species used in their traditional healing practices.

Methods: Semi-structured interviews, informal discussions and snowball sampling were performed to identify individuals with notably greater expertise regarding the uses of resources**.** The significance level among different parameters was obtained by performing two-tailed independent sample *t*-test. The ethnobotany R package, used within the R programme, was applied for creating the chord diagrams.

Results: In total, 203 informants took part in the study representing a range of age groups and different educational background. The research identifies 55 medicinal plant species, belonging to 50 genera and 28 families, with herbs (78.18%) being the most common growth form. Leaves (43.64%) formed the most commonly utilized plant part, followed by entire plants (36.36%) and roots (18.18%). The use value (UV), relative frequency citation (RFC), and relative importance index (RI) reveals that *Corydalis govaniana* and *Carum carvi* are the most valued species. Informant consensus factor (ICF) and fidelity level (FL) indices highlighted the popularity of *Podophyllum hexandrum* for menstrual irregularity and *Cicer microphyllum* for skin disorders.

Conclusions: The present study conducted in Zanskar valley shows that, regardless of education levels, both young and old generations possess a strong knowledge of medicinal plants, with a clear preference for traditional healing practices over modern medicine.

Keywords: Biodiversity, Ethnomedicinal knowledge, Key informants, Medicinal plants, Traditional healing, Zanskar, Ladakh

Background

Ladakh is distributed in five distinct valleys namely, Indus, Nubra, Changthang, Suru and Zanskar (Kaul 1997). This study focuses on the ethno-botanical research conducted in the Zanskar Valley. It is situated to the north of the main Himalayan range towards west of Leh at elevations ranging from 11,000 to 14,000 feet and is considered to be the most stunning valley of Ladakh. The Indian trans-Himalayan region spans 186,000 km^2 above the natural tree line, characterized by sparsely scattered vegetation (Chaurasia and Gurmet, 2003). Zanskar valley is isolated from the rest of Ladakh by high mountains that surround it on all sides, along with the Zanskar River. As we approach Zanskar Valley, we come across Penzi La (high mountain pass), which is the gateway to this valley. Once we traverse this pass, the different villages of the Zanskar Valley gradually unfold one by one (Lamo *et al*. 2019).

Zanskar Valley, part of the trans Himalayan cold desert landscape of Ladakh, is renowned for its unique biodiversity, particularly its rich array of medicinal flora (Chaurasia and Gurmet, 2003). This region, often isolated due to harsh climatic conditions, is home to numerous plants that have been integral to the traditional healing practices of the local communities, particularly through the Sowa Rigpa and Amchi systems of medicine (Lamo *et al*. 2019). The vegetation in the cold desert primarily consists of xerophytic, mesophytic, and oasitic plants, while the flora above the snowline is predominantly comprised of herbaceous xerophytic species (Kumar *et al*. 2011). Zargar *et al*. (2023) compiled a checklist based on field surveys conducted over the past decade, along with a thorough literature review, documenting 1,810 *taxa* (1,702 species and 108 infra-specific *taxa*) belonging to 530 genera across 91 families from Ladakh. It is estimated that around 500 plant species are utilized in the practice of Sowa Rigpa in Ladakh (Goraya and Ved 2017; Jishtu *et al*. 2023). It has been reported that nearly 70 % of medicinal plants in the trans-Himalayan region are now considered threatened due to various anthropogenic activities (Dhar *et al*. 2000).

Ethnobotany is the study of relationship between people and plants, focusing on traditional tribal cultures (Mefsin *et al*. 2013). A number of ethnobotanical studies have been conducted across Ladakh in recent times (Jishtu *et al*. 2021; Chauhan *et al*. 2022; Batool *et al*. 2023; Jishtu *et al*. 2023; Angmo *et al*. 2024). Throughout the ages, plant resources have played a crucial role in human society. Once basic needs like food and shelter were met, people turned to plants to find suitable remedies for their illnesses (WHO, 2002). For many years, medicinal plants have been employed to address a range of health issues, not only in rural regions but also increasingly in urban areas across both developed and developing nations (Huai and Pei, 2002). The World Health Organization's Global Centre for Traditional Medicine (2023) reports that approximately 88% of the global population depends on herbal medicine for their primary health care needs, especially in rural regions (WHO, 2023). Investigating and documenting these plants have been shown to be an effective approach for gaining insight into how different indigenous groups utilize natural resources, particularly for medicinal and pharmaceutical purposes (De-Albuquerque and Hanazaki, 2009). Ethnomedicinal research has played a crucial role in the creation of both natural and synthetic medications (Farnsworth, 2001).

Traditional knowledge (TK) encompasses a vast array of wisdom accumulated through experience over thousands of years. Ethnomedicinal practices are generally conveyed orally within families from one generation to the next (Nadembega *et al*. 2011), resulting in much of this knowledge remaining undocumented in a systematic manner (Zhou *et al*. 2023). Traditional medicinal practices have been experiencing a consistent decline in recent years, with no extensive research conducted on their ethnomedicinal properties. This trend is primarily attributed to the younger generation's lack of interest in traditional healing methods, the widespread deforestation, and the rapid erosion of valuable traditional knowledge due to rural depopulation (Hazarika *et al*. 2012). Recently, the global degradation of the environment has sparked concerns that modern scientific knowledge alone may not suffice for creating a sustainable development model. Therefore, it is essential to reconsider traditional knowledge for potential alternatives (Scholes *et al*. 2018). Hence, the present study was carried out to quantify and document the ethnobotanical knowledge of medicinal plants used by the local community in Zanskar Valley of UT, Ladakh.

Materials and Methods

Study area

The current investigation was carried out during August-October 2024 at Zanskar Valley of UT Ladakh, situated between 33°45'14.06'' N to 33°03'09.73'' N latitude and 77°27'41.94'' E to 77°13'44.94'' E longitude. Ethnobotanical data was collected from 29 villages (Figure 1 and Table 1) from 203 informants, including 68 males and 135 females, through random interviews and documented on a questionnaire. Among them, 42 key informants were traditional healers skilled in traditional medicine, while the remaining 161 informants, in contrast, lacked specialized knowledge and were either traditional medicine users or

information producers. The age of the informants ranged between 23 to 80 years, of which 33% were between 66 and 80 years. No discussion of confidential remedies was included in the study to safeguard the informant's intellectual property rights (IPR), and verbal consent was obtained from each participant prior to the interview. The information regarding therapeutic plants used by the indigenous people was obtained through semi-structured and unstructured interviews and informal discussions (Fig. 2a). Snowball sampling was employed to identify individuals with notably greater expertise regarding the utilization of these resources. The demographic information of informants (age, educational qualification, gender) and local plant names, their habitat, parts used for medication was also documented. Regular field visits were conducted in the study area to gather much essential data on medicinal plants, facilitating accurate identification and collection of plant samples. Approximately 10% of the population was interviewed, encompassing individuals of both genders across various age groups, with particular emphasis on elderly individuals and shepherds. A door-to-door survey was conducted in all the villages to gather as much information as possible from the locals, with a distance of about 4-5 households maintained between each interviewer. Field visits were carried out with few respondents to verify the plant specimens (Fig. 2b) mentioned during their interviews and also prepare herbarium specimens of rare plants. Plant identification was done by Dr. Vaneet Jishtu, one of the authors and from regional floras (Flora of Cold Deserts of Western Himalaya Volume 1&2 (Murti 2001; Murti *et al*. 2001), Hooker, Vol. 1-7, 1872-1897; Dorjey and Dolma 2021) and online database such as Plants of the World Online (POWO 2025).

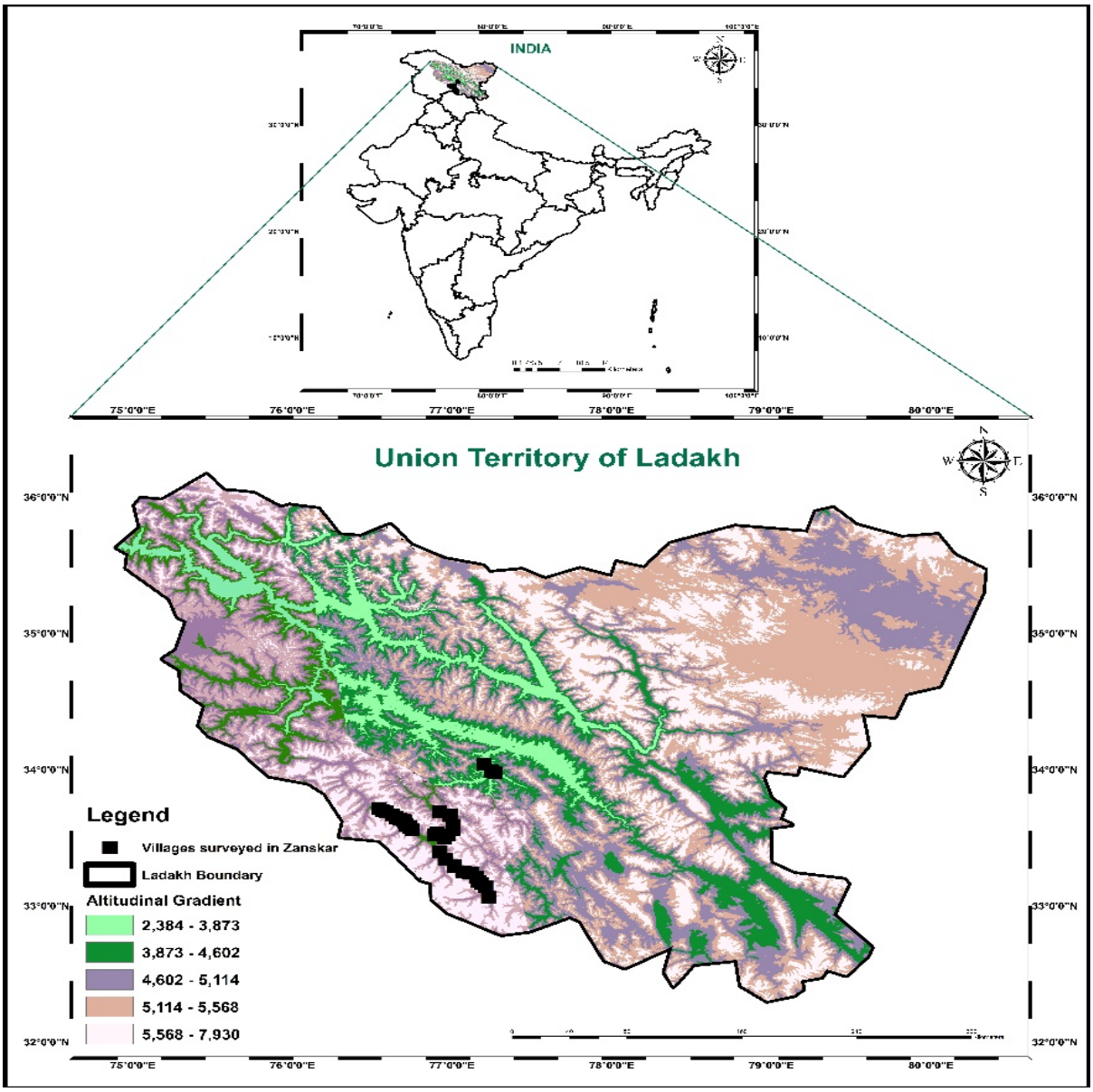

Figure 1. Map of UT Ladakh, India, showing the study site

Table 1. List of Villages studied with GPS co-ordinates.

Sr. No.	Villages	Latitude	Longitude	Altitude (m)
1	Abran	33.69580	76.56184	3763
2	Akshow	33.71532	76.61623	3840
3	Anmu	33.24605	77.07525	3883
4	Ating	33.58438	76.73147	3629
5	Chibra	33.71117	76.54385	3646
6	Chillingskit	33.55932	77.00474	3526
7	Dangze	33.13903	77.21068	3995
8	Hamiling	33.66465	76.62434	3753
9	Karcha	33.53270	76.90613	3650
10	Kargyak	33.06310	77.22733	4149
11	Kumik	33.49669	76.95385	3758
12	Kuru	33.16497	77.82850	3984
13	Kushol	33.68911	76.58604	3772
14	Mune	33.34308	76.95570	3826
15	Phey	33.61669	76.70447	3686
16	Pidmo	33.69101	76.92120	3448
17	Pipcha	33.39591	76.92335	3671
18	Reru	33.33410	76.93195	3750
19	Sani	33.50650	76.81642	3567
20	Sheela	33.43158	76.89718	3647
21	Skyagam	33.64780	76.64910	3737
22	Stongday	33.51942	76.97116	3552
23	Tankar	33.60040	76.71225	3654
24	Testa	33.17853	77.16509	4007
25	Tokta	33.59269	76.71430	3678
26	Tsazar	33.58992	77.00648	3487
27	Yall	33.20965	77.15034	3946
28	Youlang	33.51902	76.89140	3533
29	Zangla	33.66387	76.98638	3581

Data Analysis

The collected data was reviewed and organized in MS Excel based on use reports. Each column contained details such as botanical and local names, habitat, parts used, and both medicinal and other applications. Past software facilitated the execution of statistical analysis. The ethnobotany R package, utilized within the R environment, was employed for conducting quantitative analysis (Whitney 2021). Chord diagrams, depicting the utilization of plant parts and informant consensus factors, were generated using the ethnobotany R package in R software. To meet the requirements of the ethnobotany R package, the data were meticulously organized and formatted into a specific data frame. Common ethnobotany indices, derived from informant consensus, were computed using the ethnobotany R program to evaluate the cultural importance of plant species (Whitney 2021).

Quantitative indices

Use value (UV)

To assess the relative significance of the medicinal plants, use value (UV) was employed (Phillips and Gentry 1993).

$$UV = Ui/N$$

where Ui represents the number of times a particular species is mentioned, cited, or reported by each informant, and *N* is the total number of informants participated in the study. Low UV indicates fewer mentions or citations, while a high use value reflects greater frequency of use reports, or citation from the informants. Each time an informant identifies or describes a medicinal plant species used for treating a condition or another purpose, it counts as one mention or citation.

Relative frequency citation (RFC)

The relative frequency citation (RFC) is used to calculate how often a particular plant species was referenced or mentioned by the informants. It is determined using a specific formula:

RFC = FC/N

where FC represents the number of informants who cited or mentioned a specific plant, and N is the total number of informants (Tardio and Pardo 2008). The values close to 1 indicate that almost all informants mentioned a particular medicinal plant used to treat a specific illness, while a lower value suggests that the plant was cited by only a few informants, or in some cases just one.

Figure 2a. Photographs with different informants of Zanskar Valley

Cicer microphyllum Royle ex Benth.

Arnebia euchroma (Royle ex Benth.) I.M.Johnst

Corydalis govaniana Wall.

Podophyllum hexandrum Royle

Delphinium brunonianum Royle

Aconitum heterophyllum Wall. ex Royle

Figure 2b. Snapshots of the most remarkable medicinal plants found in the study area

Relative importance (RI)

The relative importance of the medicinal plants based on their use or disease category was determined using relative importance (RI) and calculated as follows:

$$RI = RFC\ (max) + RNU\ (max)/2$$

where RFC (max), (RFC (max) = FC/FC max) is the relative frequency citation of a medicinal plant species calculated by dividing the frequency citation of a particular plant species (FC) by the highest frequency citation (FC max) for any species. RNU (max), (RNU (max) = NU/NUmax) is the relative number of use categories calculated by dividing the number of use or disease

categories for a species (NU) by the number of use categories for the species with the highest number of categories (NUmax) (Tardio and Pardo 2008). High RI values indicate that a plant has been widely used to treat various diseases across multiple categories while low values suggest that a plant is applied to a limited number of disease categories; sometimes only fitting within one category.

Informant consensus factor (ICF)

The informant consensus factor (ICF) was used to evaluate the level of agreement or consistency in the informant's knowledge about the medicinal plant and it is calculated in the following way:

$$ICF = (Nur-Nt)/(Nur-1)$$

where Nur is the number of use reports or citations for each illness category and Nt is the number of species used in that particular category (Heinrich *et al*. 1998).

Fidelity level (FL)

The fidelity level (FL) was used to calculate the percentage of the most commonly used and valuable medicinal plant for a specific condition or use category based on the following formula:

$$FL\ (\%) = Np/N \times 100$$

Where NP represents the number of informants who cited or mentioned using a medicinal plant to treat a specific disease category, and N is the total number of informants who cited the plant for any other use or purpose (Friedman *et al*. 1986). A medicinal plant with a high FL value is likely to have numerous citations and be the most commonly used species for treating a particular condition.

This ethnobotanical study covered 14 distinct use or disease categories which were revised and adapted from ICD-11 (International Classification of Diseases) for Mortality and Morbidity Statistics (WHO 2024).

Results

Informant profile

The present investigation included 203 informants, and their information on age, gender, educational qualification, occupation, and healing experience are depicted in Table 2. The majority of informants were female (66.50%), while 33.50% were male. The age range of informants was 23-35 (18.23%), 36-50 (20.20%), 51-65 (28.57%), and above 66 years (33%). It was observed that the new generation continues to inherit ethnomedicinal knowledge from the elder generation, and the traditional Amchi system is preferred over the modern healthcare system. When the informants were categorized by gender, a two-tailed independent sample *t*-test revealed no statistically significant difference ($p = 0.31$) between males (mean 3.53) and females (mean 3.76) in their knowledge of documented medicinal plants. Similarly, when grouped by educational qualification and age, no significant difference was found in their knowledge of medicinal plants, with *p*-values of 0.37 and 0.26, respectively. Approximately 33% of the informants were 66 years of age or older, indicating that rural communities have a strong tradition of sharing their knowledge of medicinal plants. Based on the informant's educational qualification, those with graduate or higher education mentioned fewer plants (2.38%), followed by high school diploma (2.58%), and those who were illiterate or had elementary education (2.89%). Informants with elementary education cited more plants, as they all are senior individuals and bear extensive practical knowledge of medicinal plants, compared to those with high school diploma. Statistical analysis showed no significant difference ($p = 0.57$) in medicinal plants knowledge between informants with graduate degree and high school diploma. The results indicate that informant with a high school diploma mentioned almost the same number of plants as those with graduate or higher education. There were no statistically significant differences between informants with elementary and high school education ($p = 0.34$), or between those with elementary or graduate level education ($p = 0.27$). Although the average educational level of elementary school informants was slightly higher than that of high school informants, this difference was not statistically significant. Regarding the knowledge of medicinal plants in the study area, a significant difference was found ($p = 0.004$) between key informants and general informants, with key informants demonstrating a higher level of knowledge (4.67) compared to general informants (2.31).

Table 2 Demographic features of the informants in the Zanskar valley

Parameter	Category	Number	Frequency (%)
Sex	Male	68	33.50
	Female	135	66.50
Healing experience	Key informants	42	20.69
	General informants	161	79.31
Age (in years)	23-35	37	18.23
	36-50	41	20.20
	51-65	58	28.57
	above 66 years	67	33.00
Educational qualification	Illiterate and elementary school	154	75.86
	High school and diploma	33	16.26
	Graduate and above	16	7.88

Diversity and growth forms of medicinal plants

The current observation indicates that the indigenous community of Zanskar resides in remote areas and relies heavily on the plant resources available in their surroundings. A total of 55 ethnomedicinal plants are reported from the region which belonged to 50 genera and 28 families. The family, *Asteraceae*, being the most dominant was represented by 7 species (12.43%) and it was followed by 5 species (9.09%) each of *Amaranthaceae* and *Lamiaceae*, 3 species (5.45%) each of *Brassicaceae*, *Fabaceae*, *Polygonaceae* and *Ranunculaceae* (Figure 3).

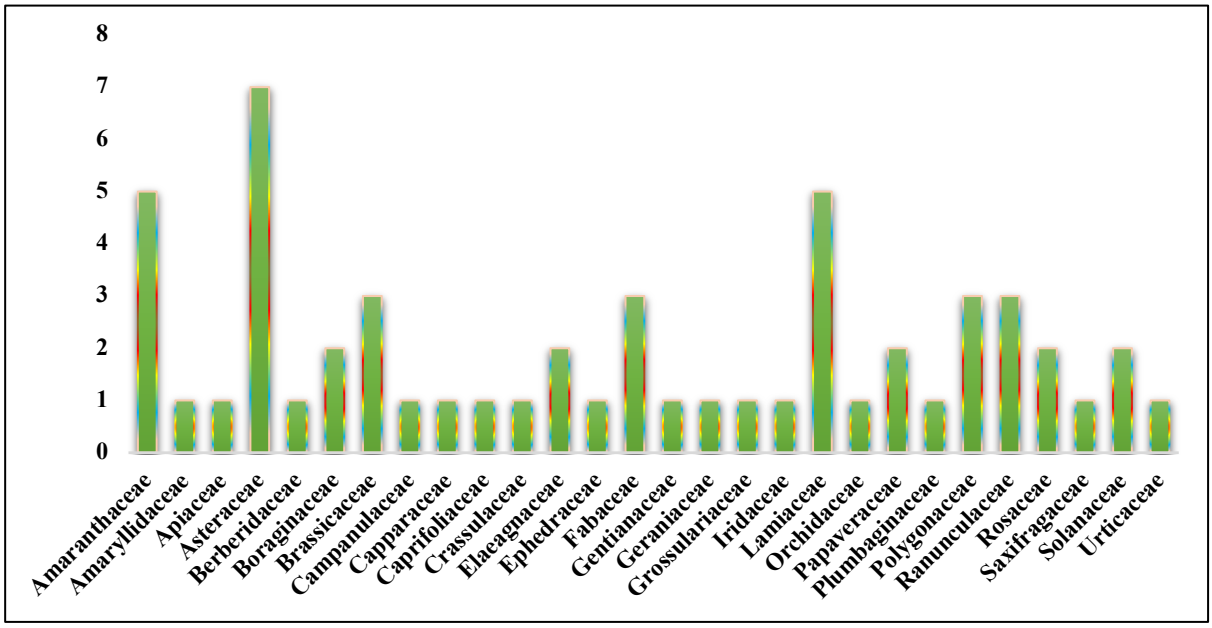

Figure 3. Family wise number of medicinal plants in the study area

Herbs and shrubs were the preferred growth forms of the therapeutic plants. The highest percentage of growth forms with 43 species was constituted by herbs (78.18%), followed by 11 shrubs (20%) and a single tree (1.82%) (Figure 4).

Plant part used for curing ailments

Although all parts of the plant were utilised in curing various human disorders, yet some specific parts of the plants were more beneficial. Here, various plant parts, including leaves, flowers, fruits, roots, seeds, shoots, stems, and entire plants are being used in traditional medicine. The most commonly utilized parts are leaves of 24 species (43.64%), followed by whole plant of 20 species (36.36%), and roots from 10 species (18.18%) (Figure 5). Whole plant (20 species), leaves (24 species), roots (10 species), stems (6 species), shoots (2 species), flowers (7 species), fruits (3 species), seeds (6 species), seeds, flowers and leaves (2 species) are being used to treat various problems. Nineteen species were used to treat cold, cough and fever, 12 species were used to treat gastrointestinal problems, nine species were used to treat anti-inflammatory effects and respiratory issues each, followed by skin-related disorders (eight species). Urogenital disorders, diarrhea and indigestion were treated by 6 species each followed by 5 species for treating rheumatism and wounds. Four species were used to treat

asthma, gastric and hematological disorders, three species was used to treat anti-microbial effects, diabetes, edema and jaundice, while 2 species each were used to treat eye ailments, hepatitis and ulcers. Abdominal pain, gum swelling, influenza, malaria, menstrual irregularities, nervous disorder and toothache each were treated by 1 species each.

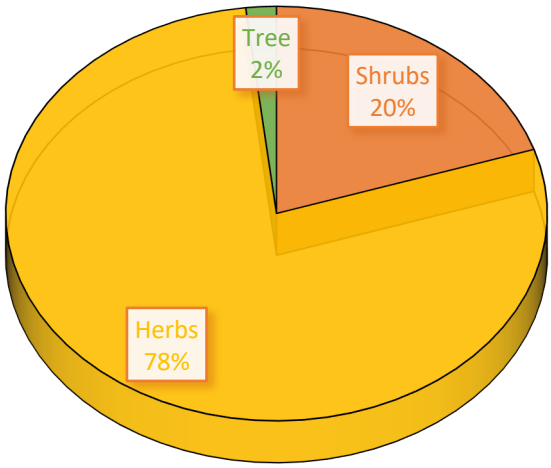

Figure 4. Growth forms of medicinal plants

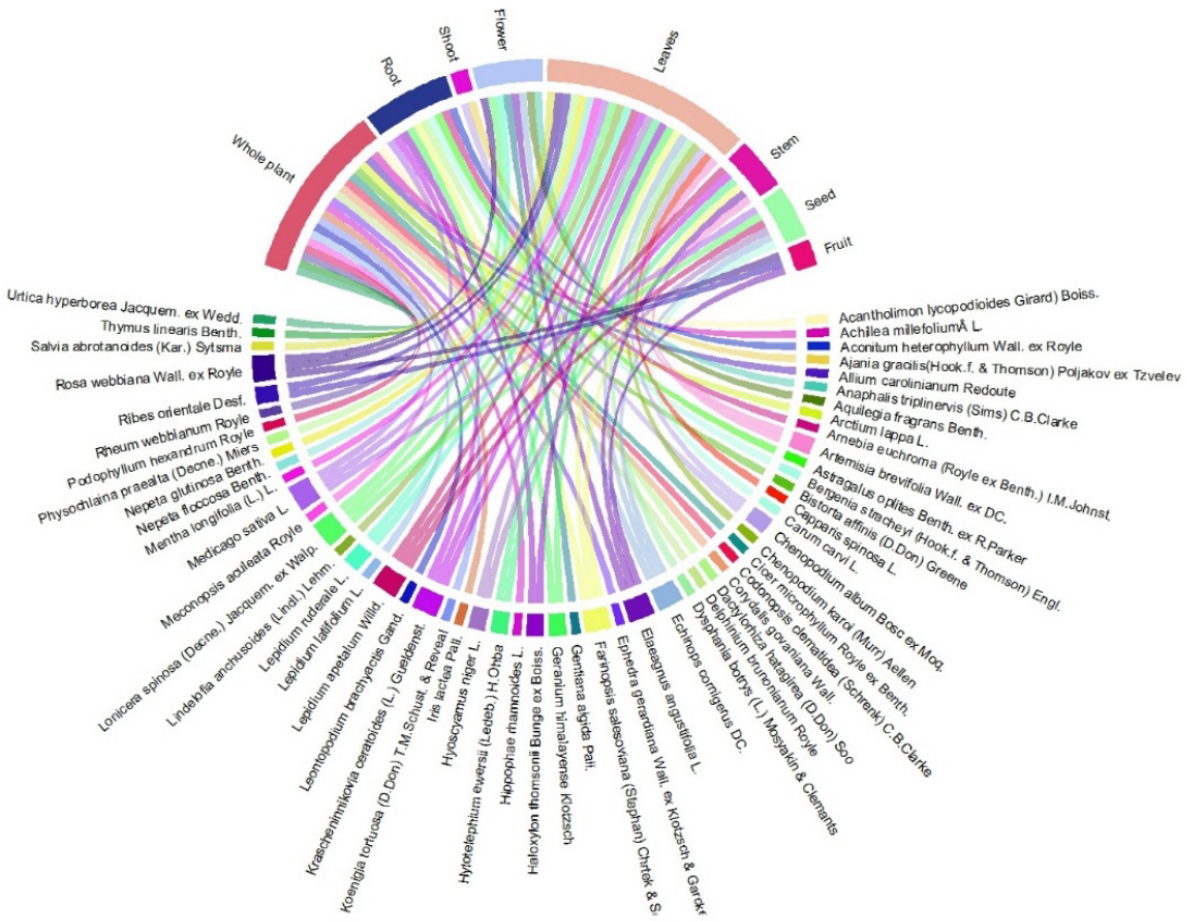

Figure 5. Utilization rate of different plant components in Zanskar valley

Use value (UV) and relative frequency citation (RFC)

To assess the use value (UV) of the documented medicinal plants, we utilized the use report (UR). This approach allowed us to evaluate the relative significance of the plants recorded in the study area and also highlighted the medicinal species favored by local indigenous communities (Table 3). The use value (UV) of *Corydalis govaniana* Wall. and *Carum carvi* L. was found to be 5.38 and 4.51, respectively, indicating the importance of local practices. Additionally, *Cicer microphyllum* Royle ex Benth. (4.38), *Podophyllum hexandrum* Royle (4.38), *Hyoscyamus niger* L. (4.34), and *Aquilegia fragrans* Benth. (4.21) also revealed significant usage values. In contrast, *Lindelofia anchusoides* (Lindl.) Lehm. (0.19) received the lowest recognition for its therapeutic potential. Among the documented medicinal plants, the highest value for relative frequency citation (RFC) was also observed for *C. govaniana* (0.27), followed by *C. carvi* (0.23) and *Podophyllum hexandrum* Royle (0.21) making them as some of the most frequently cited plants in this context.

Relative importance index (RI)

The number of uses for each medicinal plant, categorized based on use or disease, was determined using the Relative Importance (RI) index. The maximum RI value (1.00) was observed for *C. govaniana*, followed by *C. carvi* (0.84) and *P. hexandrum* (0.80). The RI results were also consistent with the UV values presented in Table 3.

Informant consensus factor (ICF)

The culturally significant medicinal plants used by local community of Zanskar valley within the same use or ailment category were evaluated using Informant consensus factor (ICF). A total of 37 diseases were identified across 11 different categories (Table 4 and Figure 6). The reproductive health category (menstrual irregularity) had the highest ICF score of 0.98, with *Podophyllum hexandrum* being the most commonly cited medicinal plant. Meanwhile the infectious disease category had the lowest ICF score of 0.92, encompassing ailments such as dysentery, fever, influenza, intestinal disease and cough.

Fidelity level (FL)

The relative significance of a medicinal plant species within each ailment or usage category was assessed using Fidelity level. The medicinal plants with the highest FL values were *Cicer microphyllum* (85%) and *Aconitum heterophyllum* (81%) (Table 4). Regarding ailments and symptoms or signs affecting skin disorders, *C. microphyllum* is the medicinal plant that is most frequently prescribed for the treatment of skin irritation. *A. heterophyllum* is the most frequently mentioned and chosen medicinal plant for treating headache under the neurological issues ailment category. Under the auto-immune disorder ailment category (rheumatism), *Lepidium latifolium* has the lowest FL (33%) value among the medicinal plants.

Table 3: Ethno-botanical uses of medicinal plants in Zanskar valley of cold desert Ladakh

Botanical Name	Local Name	Family	Habitat	Part used	Medicinal use	Other use	Status	UV	RFC	RI
Acantholimon lycopodioides (Girard) Boiss.	Longze/Burche	Plumbaginaceae	Dry rocky slopes	Wp	Diabetes and liver disorder	Fuel	LC	0.31	0.03	0.1
Achillea millefolium L.	Chuang	Asteraceae	Along pathway	Wp	Astringent; treats gum swelling	Dyeing wool	LC	0.26	0.02	0.1
Ajania gracilis (Hook.f. & Thomson) Poljakov ex Tzvelev Syn. *Tanacetum gracile* Hook.f. & Thomson	Burtse/Khamchu	Asteraceae	Stony slopes, semi-desert steppes	Sh	Intestinal disease, fever	Fodder	LC	0.44	0.04	0.12
Aconitum heterophyllum Wall. ex Royle	Bona-karpo	Ranunculaceae	Moist and damp places	Rt	High fever, toothache, stomach/gastric trouble & headache	Fodder	EN	3.89	0.08	0.52
Allium carolinianum Redoute	Koshuk	Amaryllidaceae	Alpine slopes	Wp	Cough & cold, stomach problems and menstrual pain	Flavouring agent	VU	2.30	0.06	0.32
Anaphalis triplinervis (Sims) C.B.Clarke	Spra-rgod	Asteraceae	Dry rocky slopes	Fl	Wound healing	Fodder and ornamental	VU	3.28	0.08	0.46
Aquilegia fragrans Benth.	Tama-tungtong	Ranunculaceae	Common on meadows and grazing ground	Fl	Jaundice, asthma, diabetes, headache and body pain	Ornamental	LC	4.21	0.13	0.64
Arctium lappa L.	Shiking/Pizums	Asteraceae	Open slopes	Wp	Plant paste is applied to treat blisters, pimples and burns	Salad and to flavour soups	LC	1.91	0.08	0.32
Arnebia euchroma (Royle ex Benth.) I.M.Johnst.	Demok	Boraginaceae	Dry rocky slopes	Rt	Wound healing	Colouring traditional clothes and local dishes	EN	3.17	0.12	0.51

Artemisia brevifolia Wall. ex DC.	Khampa	Asteraceae	Cultivated fields and along pathways	Le and St	stomach disorders, respiratory ailments, cough and cold	Burnt as dhoop; brooms are also made	DD	2.79	0.09	0.43
Astragalus oplites Benth. ex R.Parker	Skitchu	Fabaceae	Stony slopes	Rt	Wound healing, allergies, cold and regulates blood sugar levels	Fodder and fuelwood	NA	1.91	0.07	0.31
Bergenia stracheyi (Hook.f. & Thomson) Engl.	Tiang	Saxifragaceae	Open slopes	Rt	Used against contagious disease, influenza, inflammation of lungs & nerve, swelling of limbs; urinary problems	-	VU	2.28	0.08	0.37
Bistorta affinis (D.Don) Greene	Rambu/Bilijukma	Polygonaceae	Open slopes	Wp	To treat diarrhea, cough, cold & fever	Fodder; Flower used in religious ceremonies	NA	3.17	0.10	0.49
Capparis spinosa L.	Kabra	Capparaceae	Stony slopes and dry rocks	Bd and Le	Viral hepatitis, cirrhosis of liver, diabetes	Vegetable	LC	4.16	0.12	0.61
Carum carvi L.	Kosnyot	Apiaceae	Cultivated fields and grasslands	Sd	Cough and bronchopulmonary disorders	Condiment	LC	4.51	0.23	0.84
Chenopodium album Bosc ex Moq.	Snue	Amaranthaceae	Cultivated areas and wastelands	Le and Sh	Gastric troubles and painful urination	Fodder and vegetable	LC	4.05	0.14	0.64
Cicer microphyllum Royle ex Benth.	Sari	Fabaceae	High-altitude scree slopes	Wp	Skin disorders, Sd good source of lecithin	Shoot is edible, fodder	DD	4.38	0.15	0.69
Dysphania botrys (L.) Mosyakin & Clemants Syn. *Chenopodium botrys* L.	Snue	Amaranthaceae	Cultivated areas and wastelands	Le	Gastric troubles and painful urination	Vegetable	VU	3.65	0.13	0.58

Chenopodium karoi (Murr) Aellen	Snue	Amaranthaceae	Cultivated areas and wastelands	Le	Treats skin irritation, diuretic properties	Fodder and vegetable	NA	3.35	0.12	0.54
Codonopsis clematidea (Schrenk) C.B.Clarke	Burrkutang/Mokhting	Campanulaceae	Cultivated fields and grasslands	Wp	Treat stomach ache and enhances digestion	Flowers eaten raw	NA	2.78	0.11	0.46
Corydalis govaniana Wall.	Makshang	Papaveraceae	Moist places	Wp	As antipyretic, diuretic; helps in relieving gastric & muscular pain	Fodder	NA	5.38	0.27	1.00
Dactylorhiza hatagirea (D.Don) Soo	Ambolakpa	Orchidaceae	Grasslands and damp places	Rt	Dysentry, chronic fever, diarrhea and kidney disorders.	Used for decoration	EN	3.65	0.13	0.57
Delphinium brunonianum Royle	Ladar-mentok	Ranunculaceae	High-altitude stony slopes	Wp	Used for treating colic	Fodder & ornamental	DD	2.30	0.09	0.39
Echinops cornigerus DC.	Zbing-tser	Asteraceae	Wasteland areas	Fl, Le and Sd	Leaf paste applied to septic wounds, used as tonic and to cure jaundice	Fodder	NT	0.25	0.03	0.1
Elaeagnus angustifolia L.	Sarsing	Elaeagnaceae	Near agriculture lands	Fr, Fl and St	Cough, asthma, and diarrhea	Ornamental; as sacred offerings; timber; Fruits edible	LC	0.21	0.02	0.1
Ephedra gerardiana Wall. ex Klotzsch & Garcke	Tsepad	Ephedraceae	Hard stony stabilized places, arid habitat	Wp	Fever, hepatic diseases, and bronchial asthma	Fruits edible	VU	2.22	0.09	0.37
Farinopsis salesoviana (Stephan) Chrtek & Soják Syn. *Potentilla salesoviana* Stephan	Shour/Naghardom	Rosaceae	Wet grasslands	Le, St and Rt	Liver problem, regulating blood sugar levels, anti-microbial & anti-inflammatory	Ornamental and in traditional rituals	LC	0.48	0.03	0.11
Gentiana algida Pall.	Tikta	Gentianaceae	Open moist slopes	Fl	Used to treat bronchitis, cough,		LC	3.27	0.11	0.50

					hoarseness of throat and epidemic fevers	Fodder			
Geranium himalayense Klotzsch	Phorlo/Gadur mentok	Geraniaceae	Wet areas, river and stream banks	Le and Rt	Fever, skin irritations and indigestion	Aesthetic value and fodder	LC	1.41	0.06	0.25
Haloxylon thomsonii Bunge ex Boiss.	Saksaul	Amaranthaceae	Dry slopes, semi-arid and arid places	Le, Br and Rt	Hepatobiliary & eye disorders; hemorrhoids, fever, skin disease & diarrhea	Firewood	DD	1.34	0.06	0.23
Hippophae rhamnoides L.	Tsermang	Elaeagnaceae	River belts and wastelands	Wp	Anti-ageing, anti-cold and helps in memory restoration & energy boosting	Herbal beverage and herbal tea	LC	3.89	0.15	0.64
Hylotelephium ewersii (Ledeb.) H.Ohba	Chunke-chang	Crassulaceae	Rocky slopes, open grasslands and disturbed areas	Le and St	Wound healing, skin irritation, gastrointestinal discomfort, anti-inflammatory; analgesic	Ornamental purpose	NE	3.23	0.13	0.55
Hyoscyamus niger L.	Gya-lantang	Solanaceae	Cultivated areas	Sd and Le	Nervous diseases, Sd used in teeth infection & asthma	Fodder	VU	4.34	0.19	0.76
Iris lactea Pall.	Krisma	Iridaceae	Cultivated areas and water channels	Wp	Treat jaundice, respiratory issues; gastrointestinal disorders	Fodder, ornamental & aesthetic value	LC	0.30	0.04	0.11
Koenigia tortuosa (D.Don) T.M.Schust. & Reveal Syn. *Aconogonon tortuosum* (D.Don) H.Hara	Ranbotsuk	Polygonaceae	High-altitude slopes, roadsides riverbanks,	Wp	Painful urination	Fodder	DD	1.69	0.07	0.29
Krascheninnikovia ceratoides (L.) Gueldenst.	Teresken	Amaranthaceae	Open grasslands,	Le, Rt and St	Wound healing, anti- inflammatory	Fodder	NT	0.56	0.05	0.14

			semi-desert steppes		properties, cough and bronchitis				
Leontopodium brachyactis Gand.	Tsa-tsa	Asteraceae	High-altitude moist rocky slopes, meadows	Wp	Abdominal pain, diarrhea, anti-inflammatory and anti-microbial properties	Fodder and ornamental purpose	NE	2.16	0.10	0.39
Lepidium apetalum Willd.	Taa	Brassicaceae	Stony slopes	Sd, Le and St	Used to treat ulcers and edema	Vegetable and spices	DD	3.19	0.14	0.56
Lepidium latifolium L.	Shang-sho	Brassicaceae	Stony slopes, along streams	Wp	Rheumatism, prevents kidney hemorrhage	Vegetable	LC	2.58	0.12	0.46
Lepidium ruderale L.	Mankhayi	Brassicaceae	Meadows and disturbed areas	Le and Fl	Skin problems & anti-microbial; in rheumatism	Ornamental	LC	2.70	0.13	0.50
Lindelofia anchusoides (Lindl.) Lehm.	Makpen/Pizums	Boraginaceae	Stony slopes	Le	Diarrhea	Fodder	DD	0.19	0.03	0.1
Lonicera spinosa (Decne.) Jacquem. ex Walp.	Khe-strak	Caprifoliaceae	Alpine slopes and drier areas	Fl, Sd & Le	Cough, cold and fever	Source of fuel	NE	1.38	0.09	0.30
Meconopsis aculeata Royle	Landermentok	Papaveraceae	High-altitude stony slopes	Wp	To treat ulcers, lung disorder, liver and inflammation	Ornamental	CE	1.73	0.10	0.34
Medicago sativa L.	Buksuk	Fabaceae	Cultivated areas	Le, Rt and Sd	Swelling, urination, indigestion, anti-inflammatory and analgesic	Vegetable	LC	2.35	0.13	0.45
Mentha longifolia (L.) L.	Phololing	Lamiaceae	Near fields & stream banks	Le	Anti-dysenteric	Vegetable	LC	4.05	0.18	0.71
Nepeta floccosa Benth.	Shalmazok	Lamiaceae	Rocky and dry slopes	Le	Cough, cold and malaria	Condiments	DD	1.75	0.11	0.36
Nepeta glutinosa Benth.	Jatukpa	Lamiaceae	Rocky dry slopes & roadsides	Le	Diarrhea	Spices	DD	3.04	0.15	0.56

Physochlaina praealta (Decne.) Miers	Langtang	Solanaceae	Cultivated areas	Le	To treat ulcer and eye diseases	Preparation of organic manure	DD	2.42	0.14	0.48
Podophyllum hexandrum Royle	Denmokushu	Berberidaceae	Cultivated fields and moist areas	Wp	To cure menstrual irregularity, high-altitude mountain sickness; improves blood circulation	Young and ripe Fruits are edible	EN	4.38	0.21	0.80
Rheum webbianum Royle	Khawal/Lachhu	Polygonaceae	Open slopes and shrubberies	Wp	To cure indigestion, gastritis, abdominal disease, boils & wounds	-	VU	3.67	0.19	0.70
Ribes orientale Desf.	Nyashing/Khestrak	Grossulariaceae	Mountainous terrains, scrublands, open grasslands	Le and Fr	Indigestion, blood purification, respiratory and gastrointestinal issues	Fruits are edible and used as fuelwood	DD	2.56	0.14	0.50
Rosa webbiana Wall. ex Royle	Syah-marpo	Rosaceae	Dry and Rocky slopes	Le, Fl and Fr	Cough, cold, skin ailments, gastrointestinal discomfort, hepatitis	Used as fodder and fuelwood	DD	3.01	0.16	0.58
Salvia abrotanoides (Kar.) Sytsma Syn. *Perovskia abrotanoides* Kar.	Skilling/Kikiling	Lamiaceae	Stony slopes and farming areas	Le	Control painful urination, cough and headache	Fodder	DD	1.53	0.09	0.31
Thymus linearis Benth.	Tikta	Lamiaceae	Rocky slopes and open grasslands	Wp	Headache, indigestion, anti-inflammatory properties	Spices	DD	2.45	0.15	0.50
Urtica hyperborea Jacquem. ex Wedd.	Dzatsutt	Urticaceae	Open forest, rocky slopes	Wp	Joint pain, cough and cold	Used to make thukpa	DD	1.02	0.04	0.18

Legend:

Part used: Wp = Whole plant, Le = Leaf, Fl = Flower, Fr = Fruit, Rt = Root, Sd = Seed, St = Stem, Sh = Shoot, Br = Branch, Bd = Bud

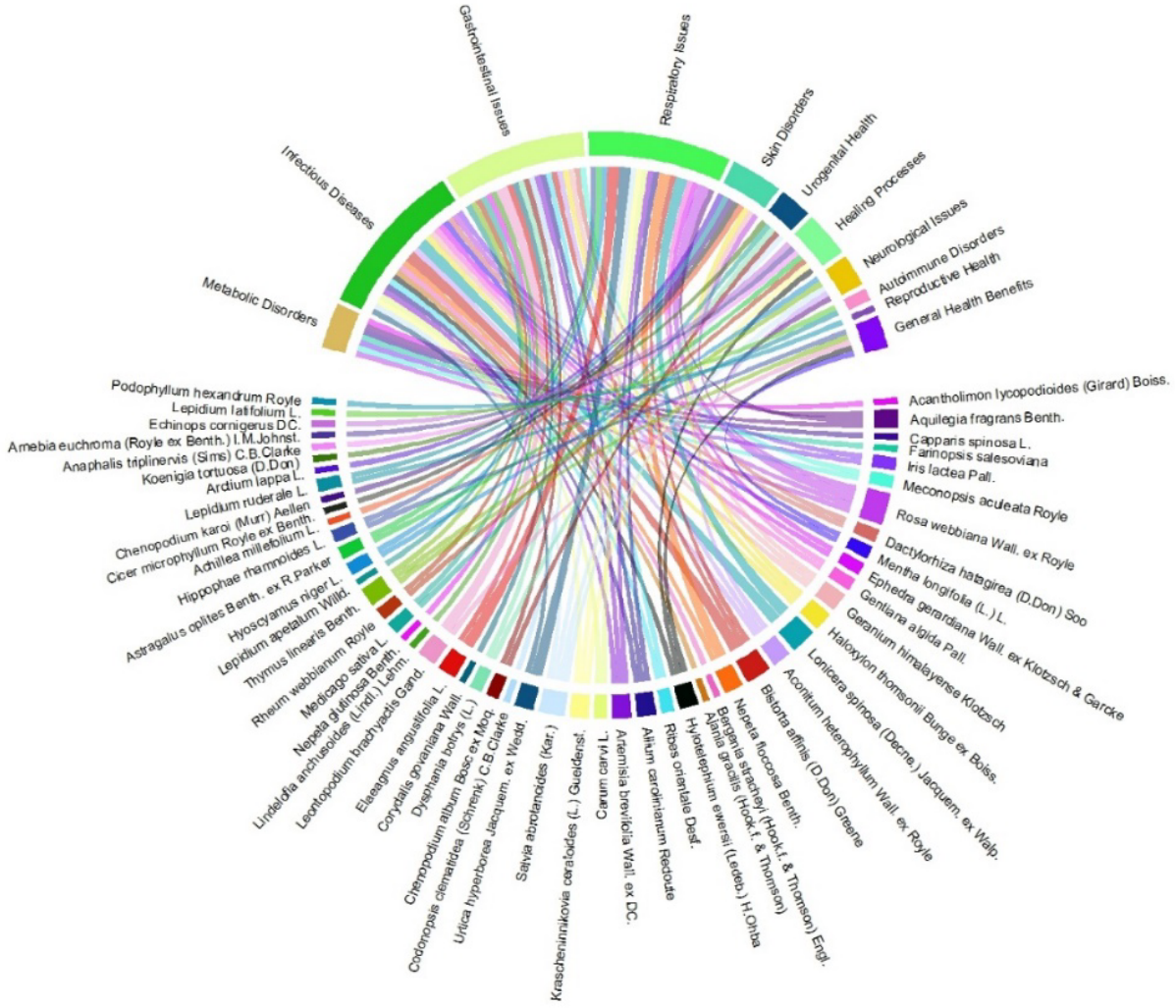

Figure 6. Analysis of informant consensus factor from Zanskar valley

Comparative analysis of quantitative indices

Table 5 shows the ranking of medicinal plants with the most disease or use categories, UV, RFC, and RI values. Medicinal plants with the highest UV, RFC, and RI values are the most highly regarded and culturally significant in the Zanskar valley. Their evaluation involves analyzing the number of usage reports, the frequency of citations from informants, and the different applications or purposes across various ailment categories. In all three indices, the top 10 medicinal plants were nearly identical, with the possible exceptions of *Bergenia stracheyi*, *Haloxylon thomsonii*, *Hylotelephium ewersii*, and *Medicago sativa* being listed in the NU (number of use). These four plants are highly versatile with numerous applications; however, their UV, FC, and RI values are lower than those of other plant species. A particular medicinal plant is considered to have low usage reports, citation frequency, and disease categories if its UV, RFC. And RI values are low. The present study also revealed similarities between the UV, RFC, and RI values among certain reported species. However, each index provides a distinct rating for each species. Based on both RFC and UV indices, *C. govaniana* is ranked first. This may be due to the fact that this species is the most well-known plant in majority of the study sites and is frequently mentioned by the informants. It has been suggested that use value, is a more reliable indicator of use diversity than citation count (Da Silva *et al*. 2006). Accordingly, the plant most commonly used in our study determines the UV value instead of the species cited by more informants. RI is determined by the degree of diversity in medical applications, here *C. govaniana* ranks as first and *C. carvi* ranked as second in the index. The *taxa* having high levels of diversity and use for the treatment of multiple ailments may account for its top ranking in RI. The RI was developed as a general indicator of use diversity, without considering the number of informants, and both more specialized uses and the flexibility of use categories serve as its foundation. However, the average number of use reports for each informant and species is provided by the UV and RFC. This could be the reason for the differences in the rankings of RI, UV and RFC. Furthermore, a significant strong positive correlation was found between

the relative importance of plant use and the regional importance of each medicinal plant, as demonstrated by the Pearson correlation coefficient of 0.87 ($p < 0.003$) between RFC and UV. The results are consistent with earlier studies that also reported a high positive correlation between RFC and UV (Ralte *et al*. 2024; Ahmad *et al*. 2017; Bano *et al*. 2014). Further, correlation between RFC and RI was also found to be positive for the medicinal plants (r = 0.96, $p < 0.001$), suggesting that they are valued not just for one specific use but have multiple applications in traditional medicine. Based on the participant consensus, utility in treating illnesses, and species origin, we conclude that RFC and RI are dependent. According to the citations provided by the informants, high use value, and a wide range of applications in numerous disease categories, *C. carvi*, *C. govaniana* and *P. hexandrum* are the most culturally cherished, valued, recommended, and important medicinal plants among the indigenous people of Zanskar valley.

Table 4. Ailment category, disease under each category, number of plants used, use report, ICF, FL, most cited taxa and purpose of most cited taxa

Ailment category	**Disease under each category**	**Number of plants used**	**Use report**	**ICF**	**FL (%)**	**Most cited taxa**	**Purpose of the most cited taxa**
Metabolic disorders	Diabetes, liver disorder, viral hepatitis and cirrhosis of liver	08	108	0.93	53	*Capparis spinosa*	Diabetes
Infectious diseases	Dysentery, fever, malaria, influenza, intestinal disease, cough (including bronchopulmonary disorders)	21	260	0.92	74	*Haloxylon thomsonii*	Fever
Gastrointestinal issues	Stomach problems, gastric troubles, diarrhea, indigestion, abdominal pain and ulcers	23	304	0.93	66	*Dactylorhiza hatagirea*	Diarrhea
Respiratory issues	Asthma, cold, cough and bronchitis	17	248	0.94	45	*Aquilegia fragrans*	Asthma
Skin disorders	Gum swelling, skin irritation, blisters, pimples and burns	10	134	0.93	85	*Cicer microphyllum*	Skin irritation
Urogenital health	Painful urination and kidney disorder	05	69	0.94	37	*Chenopodium album*	Painful urination
Healing processes	Wound healing (including septic wounds)	06	72	0.93	69	*Arnebia euchroma*	Wound healing
Neurological issues	Headache and nervous diseases	05	92	0.96	81	*Aconitum heterophyllum*	Headache
Auto-immune disorders	Rheumatism	02	25	0.96	33	*Lepidium latifolium*	Rheumatism
Reproductive health	Menstrual irregularity	02	42	0.98	58	*Podophyllum hexandrum*	Menstrual irregularity
General health benefits	Energy boosting, anti-inflammatory and anti-dysenteric properties	08	119	0.94	77	*Mentha longifolia*	Anti-dysenteric properties

Table 5. Medicinal plants with the highest number of therapeutic application (NU), UV, RFC, and RI

Rank	Plant	NU	Plant	UV	Plant	RFC	Plant	RI
1	*Bergenia stracheyi*	6	*Corydalis govaniana*	5.38	*Corydalis govaniana*	0.27	*Corydalis govaniana*	1.00
2	*Aconitum heterophyllum*	5	*Carum carvi*	4.51	*Carum carvi*	0.23	*Carum carvi*	0.84
3	*Aquilegia fragrans*	5	*Cicer microphyllum*	4.38	*Podophyllum hexandrum*	0.21	*Podophyllum hexandrum*	0.80
4	*Haloxylon thomsonii*	5	*Podophyllum hexandrum*	4.38	*Hyoscyamus niger*	0.19	*Hyoscyamus niger*	0.76
5	*Hylotelephium ewersii*	5	*Hyoscyamus niger*	4.34	*Rheum webbianum*	0.19	*Mentha longifolia*	0.71
6	*Medicago sativa*	5	*Aquilegia fragrans*	4.21	*Mentha longifolia*	0.18	*Rheum webbianum*	0.70
7	*Podophyllum hexandrum*	5	*Capparis spinosa*	4.16	*Rosa webbiana*	0.16	*Cicer microphyllum*	0.69
8	*Rheum webbianum*	5	*Chenopodium album*	4.05	*Cicer microphyllum*	0.15	*Aquilegia fragrans*	0.64
9	*Rosa webbiana*	5	*Mentha longifolia*	4.05	*Hippophae rhamnoides*	0.15	*Chenopodium album*	0.64
10	*Corydalis govaniana*	4	*Aconitum heterophyllum*	3.89	*Nepeta glutinosa*	0.15	*Hippophae rhamnoides*	0.64

Discussion

In the present investigation 66.50% of informants are female, showing their keen interest in traditional healing practices. The females in Zanskar valley are actively involved in the collection of local herbs and typically prefer to impart their traditional knowledge to other people. The higher number of female informants is also attributed to the fact that the males often leave the valley in search of work to meet their economic needs. Likewise, results from other research carried out in Zanskar (Batool *et al*. 2023) and worldwide (Chaachouay *et al*. 2019; Abbas *et al*. 2016; Tuler and Silva 2014; Guimbo *et al*. 2011) also showcased female preponderance. The most prevalent families identified were *Asteraceae*, *Amaranthaceae* and *Lamiaceae*, likely due to the greater adaptability of species within these families across a broader range of altitudes. The *Asteraceae* family is recognized as the most prevalent (Mir *et al*. 2021; Asif *et al*. 2021; Nafeesa *et al*. 2021; Singh *et al*. 2017) due to their broad ecological range, and *Asteraceae* species can quickly adjust and thrive in dry, arid environments (Haq *et al*. 2021). Pala *et al*. (2019) recognized *Lamiaceae* as the most prominent family in the Eastern Himalaya, which corresponds with our observations. The *Lamiaceae* family, consisting of 236 genera and encompassing 6900-7200 distinct *taxa*, is known for its diverse aromatic properties, including volatile and essential oils, as well as terpenoids, phenolics, alkaloids, and flavonoids (Frezza *et al*. 2021; Vescio *et al*. 2021). Nearly all of these plant *taxa* have been utilized in the food and pharmaceutical sectors to create value-added flavor and fragrance products that benefit human health (Dutta *et al*. 2021; Valerio *et al*. 2021; Singh *et al*. 2020). Comparable findings were also documented in earlier studies (Ralte *et al*. 2024; Jishtu *et al*. 2022; Umair *et al*. 2017; Bano *et al*. 2014).

The most commonly recorded plant species are the herbs. This may be due to the local population's accessibility to abundant resources. Likewise, numerous ethnobotanical studies conducted in Ladakh (Batool *et al*. 2023; Ballabh *et al*. 2008), other regions of India (Ralte *et al*. 2024; Jishtu *et al*. 2021; Singh *et al*. 2017) and by various nations (Rehman *et al*. 2022; Karakose, 2022; Faruque *et al*. 2018; Tuler and da Silva 2014) have also highlighted the predominant use of herbs in traditional medicine. In the current investigation, most of the medicinal plant parts utilized for addressing health issues are leaves that align with the findings from local studies (Batool *et al*. 2023; Haq *et al*. 2021; Kala 2006) as well as other states (Ralte and Singh 2024; Ralte *et al*. 2024; Balamurugan *et al*. 2018; Rao *et al*. 2015; Bhatia *et al*. 2014) and other nations (Rehman *et al*. 2022; Emre *et al*. 2021; Umair *et al*. 2017). Leaves are rich in a variety of phytochemicals that contribute to their therapeutic properties (Rao *et al*. 2023) and their effectiveness in traditional medicine is closely linked to their rich phytochemical content, which includes flavonoids, tannins, saponins, glycosides, terpenoids, alkaloids, and phenolics (Dubale *et al*. 2023; Zulkurnain *et al*. 2023). These compounds offer a scientific foundation for the various therapeutic uses of leaves, such as promoting wound healing, controlling infections and reducing inflammation (Zulkurnain *et al*. 2023). Furthermore, the locals hold the view that the plant's leaves are rich in secondary metabolites and essential oils. As a result, they regard the leaves

as more effective for use in nutraceutical medicine, phytotherapy, or addressing various health issues (Sicari *et al*. 2021; Katare *et al*. 2020; Amjad *et al*. 2017). Leaves are often more readily available than other plant parts such as roots or flowers (Singh *et al*. 2020; Ojha *et al*. 2020). This accessibility makes it easier for local communities to gather them for medicinal purposes, especially in remote areas, where resources may be limited. Harvesting leaves is more sustainable than harvesting roots or uprooting entire plants, as it allows the continued growth and availability of these plants in the wild (Ralte *et al*. 2024). This practice aligns with local traditions of conserving biodiversity while meeting health needs. Ladakh's unique flora includes a variety of plant species whose leaves are used in traditional remedies and the region's biodiversity supports a rich tapestry of herbal medicine practices that rely heavily on leaves.

There was no significant difference in the mean number of medicinal plants mentioned by male and female interviewees in the Zanskar valley. This indicates that all families interviewed in the study area possessed a similar level of knowledge and both men and women share the responsibility for delivering basic health care. Similarly, previous reports also found no significant difference in medicinal plant knowledge between men and women (Ralte *et al*. 2024; Ralte and Singh 2024; Tahir *et al*. 2021; Chaachouay *et al*. 2019). Predictably, key informants possessed greater expertise than general informants, as previously documented by many authors (Ralte *et al*. 2024; Tahir *et al*. 2021; Giday *et al*. 2009). This can be attributed to the fact that key informants actively engage in traditional medicine and ethnobotanical practices, allowing them to gain practical experience and deepen their understanding of medicinal plants and their properties.

Among the recognized medicinal plants, *C. govaniana* exhibited the highest values for UV, RFC and RI indicating that it is the most valued and preferred medicinal plant for treating various diseases across multiple ailment categories. The phytochemical compound, Govaniadine (Sivakumaran *et al*. 2018), a major component of *C. govaniana*, possesses numerous biological potentials, such as, antibacterial (Zamperini *et al*. 2017), anti-oxidant (Shrestha and Adhikari 2017), anticancer, anti-inflammatory, antithrombotic, antidiabetic and chemotherapeutic (Saczewski and Balewski 2009).

The current investigation documented a total of 1,473 use reports for 35 ailments across 11 categories based on ICD-11 disease classifications (Table 4). The Informant Consensus Factor (ICF) was calculated to evaluate the consistency of the collected information and Heinrich *et al*. (1998) emphasized that a high ICF indicates a greater likelihood of discovering valuable bioactive compounds and is essential for prioritizing the conservation of species amid declining medicinal plants. The ICF values for medicinal plants varied from 0.92 to 0.98, in Zanskar valley. Reproductive health was having highest ICF = 0.98 (42 UR and 1 spp.). It is important to note that this category included only one condition (menstrual irregularity) and one species (*P. hexandrum*). This medicinal plant species is commonly found in Zanskar valley, Ladakh, and the local agrees that it can be used to treat menstrual irregularities in both present and previous studies (Shabir *et al*. 2023; Sharma and Sharma, 2023; Anand *et al*. 2022; Angmo *et al*. 2019; Li *et al*. 2015; Dhar *et al*. 2002). The plants *C. microphyllum* (85%) and *A. heterophyllum* (81%) exhibited the highest FL values for alleviating skin irritation and headache, respectively. These findings suggest that the respective plants possess significant healing potential. Research utilizing phytoextraction to demonstrate the efficacy of bioactive compounds can be enhanced by selecting plants that display high FL values.

The conservation and management of biological resources in Zanskar face significant challenges primarily due to unsustainable harvesting practices, especially concerning medicinal plants. In the current investigation, the 55 medicinal plants documented in the region are classified under various levels of threat according to IUCN criteria (IUCN 2024) and local assessments. In Zanskar, the extreme climatic conditions and geographical isolation contribute to a rich diversity of medicinal plants. However, overharvesting driven by trade pressures poses a major risk to these species. The study indicates that several plants are classified as endangered or vulnerable, while many others are threatened by habitat degradation, overgrazing, and climate change.

Health implications of the current study for the local community

The most common health issues in the investigated area are presented in Table 4. In the present study, medicinal plants used for the treatment of each of these ailments are thoroughly documented. Several plant species are used in the treatment of stomachaches, gastric issues, diarrhea, indigestion, diabetes, liver disease, and viral hepatitis, while also offering therapeutic benefits for other conditions. These plant species such as *A. euchroma*, *A. heterophyllum*, *C. spinosa*, *D. hatagirea*, *A. lycopodioides*, and *R. webbianum* have been reported for the treatment of various ailments worldwide (Wani *et al*. 2022; Kumar *et al*. 2021; Parvez *et al*. 2020; Wani *et al*. 2020; Hosseini *et al*. 2018; Zhang and Ma 2018; Nabavi *et al*. 2016; Tabin *et al*. 2016). In Zanskar, variability in snowfall and increasing temperature due to climate change force residents to rely on rivers, increasing the risk of waterborne diseases, including diarrhea, due to potential contamination. This dependency causes diarrhea to be one of the most prevalent health issues in the region. The National Family Health Survey

(NFHS-5) reveals that the prevalence of diarrhea among children under five in Ladakh increased from 3.1% in 2015-16 to 8.5% in 2019-20 (IIPS 2021). This rise underscores the persistent public health issues faced by isolated rural communities, where access to conventional medical care is limited during critical infection periods. Similar studies were also reported in Mizoram (Ralte *et al*. 2024), neighboring nations (Faruque *et al*. 2018; Abbas *et al*. 2016; Bano *et al*. 2014) and other developing countries such as Ethiopia (Damtie 2023; Woldeab *et al*. 2018), Nigeria (Osuntokun *et al*. 2017), South Africa (Ndhlovu *et al*. 2023), Uganda (Anokbonggo *et al*. 1990), and Zimbabwe (Pitts *et al*. 1996). Therefore, it is essential to evaluate potential agents with anti-stomachache, anti-diabetic, anti-diarrheal, anti-hepatitic, and anti-ulcer properties to identify novel bioactive compounds for new drug formulations. Medicinal plants have gained significant attention in Zanskar valley of Ladakh, particularly for their therapeutic properties. Local healers (Amchi) utilize various plants, such as the juice of *Hippophae rhamnoides* subsp. *turkestanica* (sea buckthorn), traditionally used to treat a range of ailments, including infections, digestive issues, and skin problems. In Ladakh, traditional medicine-particularly the Sowa-Rigpa system practiced by the Amchi's, has a rich history of using medicinal plants to treat various ailments. Research has documented numerous species utilized by these practitioners, emphasizing their role in community health. Additionally, initiatives such as the establishment of herbal gardens by institutions like the National Institute of Sowa Rigpa (NISR) aim to protect endangered medicinal plant species while promoting sustainable practices among local farmers. These efforts align with the broader goal of integrating traditional knowledge with modern conservation strategies. To ensure that this ethnobotanical knowledge remains a vital part of Ladakh's cultural heritage and continues to support local economic growth and health, it is essential to keep documenting and validating it.

Comparison with earlier ethnobotanical research

The Trans-Himalayan cold desert region is known for its unique flora, and several studies have been conducted on ethnobotany, but very little research is based on quantitative analysis. The study on ethnobotanical treasures of Zanskar valley is carried out for the first time and provides a reference for future investigations to be conducted in the cold desert regions. Due to the extreme climatic conditions and rough terrain of Ladakh, few studies are concentrated on particular indigenous communities. Most ethnobotanical studies deliberately selected key informants, such as elders, traditional healers, herbalists, and residents, who were exclusively knowledgeable about therapeutic plants. But, in the present study key informants along with general informants were interviewed about the use of medicinal plants in their daily life. Although the key informants had a higher level of knowledge compared to the general informants, it is important to note that this distinction highlights the specialized expertise and experience of the key informants.

A critical review of various studies conducted in Ladakh over the past few decades reveal that indigenous communities have recorded a total of 502 medicinal plant species belonging to 74 families and 261 genera for medicinal purposes (Batool *et al*. 2023). In previous investigations, the *Asteraceae* family (102 species) has been found to be the most dominant in Ladakh, a finding that we also reported in Zanskar. Till now, quantitative analyses of ethnobotanical studies have not featured in Zanskar. Similar views were also reported by Batool *et al*. (2023), while reviewing the previous studies in Ladakh. An earlier study from Ladakh has also recorded *E*. *gerardiana* as a potential medicinal plant for treating fever, which is comparable to the present study (Haq *et al*. 2021). *Nepeta glutinosa* has been found to be effective against diarrhea in a study conducted by Hussain *et al*. (2023). The results indicate a greater consensus among Ladakh residents regarding the uses of plants and their associated traditional knowledge. This study also lays the groundwork for future research to be conducted in Ladakh.

Risks to traditional medicinal knowledge and medicinal plants

The current study indicated that most informants in the Zanskar Valley fell within the age range of 35 to 65 years, and individuals in this group demonstrated a substantial understanding of medicinal plants. The heritage of traditional medicine can manifest in various ways. It may be transmitted within families, acquired through self-study, gained via practical training, accumulated over time, or through the collection of medicinal formulations. However, the origins and details of these therapeutic practices remain unclear due to the absence of a written tradition. The use of traditional medicine is more common in the studied regions, due to the non-availability of modern medical options, and the local population continues to rely on the Amchi system for healing. However, the younger generation is not showing interest in traditional healing practices due to a lack of awareness. This poses a significant threat to traditional medicinal knowledge, as the younger generation lacks interest in preserving the legacy of their ancestors for future generations. Additionally, overharvesting of medicinal plants for commercial purposes, coupled with habitat destruction due to agricultural expansion and land-use changes, poses significant threats to the biodiversity of plant species used for medication. The lack of scientific cultivation methods and awareness further aggravates the situation, putting many important medicinal plants at risk of extinction and jeopardizing the cultural heritage associated with them. Traditional medicine in Ladakh is not merely a method of treatment for the indigenous people; it serves as a vital symbol of their cultural identity. The present findings emphasize the significance

of preserving and promoting traditional knowledge of medicinal plants to protect cultural heritage and foster sustainable development. The transmission of this medicinal knowledge is essential for maintaining and advancing minority cultures, ensuring that the wisdom of the past is passed down to future generations in Ladakh. Various stakeholders, including the government, academics, communities, and local healers, are working together to protect the endangered culture of traditional medicine. These collaborative initiatives focus on documenting and preserving traditional knowledge, providing training and education to local healers and younger generations, and creating strategies for the future development of this invaluable information (Ralte *et al*. 2024; Guler *et al*. 2020).

Conclusion

The findings of this study underscore the significant role of medicinal plants in the traditional healthcare system of the Zanskar Valley. The indigenous knowledge, particularly regarding the use of plants like *Corydalis govaniana*, *Carum carvi*, and *Podophyllum hexandrum*, remains a critical component of local healthcare practices, despite the growing influence of modern medicine. The entire community in the Zanskar valley continues to rely on the traditional Amchi practice for treating a variety of illnesses, and they possess extensive knowledge of medicinal plants. The data also demonstrate the profound connection between plant use and cultural traditions, with key informants showing more in-depth knowledge compared to general informants. Additionally, the analysis of various indices such as UV, RFC, and RI reveals a strong correlation between the diversity of medicinal plant uses and their cultural importance. This study highlights the need for preserving traditional ethnobotanical knowledge, as it remains integral to the health and well-being of the local population in remote regions like Zanskar. The tradition of utilizing local plants for medicinal and other customary purposes has been passed down through generations. In this regard, species with significant UV potential can be bio-profiled to potentially discover new molecules with powerful medicinal attributes. Further efforts should be made to document and safeguard this knowledge for future generations, ensuring the continued application of these valuable resources in modern healthcare systems. This paper will also assist people worldwide in becoming familiar with the ethnobotanical treasures found in their regions. Scientists can investigate how these medicinal plants might be employed by pharmaceutical companies to develop a range of medications. This study will serve as a crucial reference point for upcoming research in botany, pharmacology, and conservation.

Declarations

List of abbreviations: ICF - Informant Consensus Factor**;** UV - Use Value; FL - Fidelity Level; RFC - Relative Frequency Citation; RI - Relative Importance Index; ICD-11 - International Classification of Diseases; IUCN - International Union for Conservation of Nature; NE - Not Evaluated; LC - Least Concern; EN – Endangered; CE - Critically Endangered; NT - Near Threatened; VU – Vulnerable; DD - Data Deficient; NU - Number of Use; NA - Not Available

Ethics approval and consent to participate: The study participants provided their consent for inclusion in the research. Before initiating field investigations, permission was acquired from the local communities involved. All persons shown in images gave their consent to have the image publiushed.

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