Relation of medicinal plants, their use patterns and availability in the lower Kailash Sacred Landscape, Nepal

Ripu M. Kunwar, Keshab Shrestha, Sulochan Malla, Tulasi Acharya, Arthur J. Sementelli, Durga Kutal*, Rainer W. Bussmann

Research

Abstract

Background: Conservation of useful plants can be maintained and enhanced once the nature of a cultural landscape and knowledge and principles of resource utilization are understood. We studied the factors influencing indigenous knowledge of medicinal plant collection and utilization in the lower Kailash Sacred Landscape, Nepal.

Methods: A total of 62 respondents aged ≥ 60 years, including 42 plant collectors and 20 traditional healers from nine villages of Baitadi, Dadeldhura and Darchula districts, far western Nepal were consulted for this study following snow-ball sampling and village references.

Results: Results showed that the area is rich in useful plants and indigenous therapeutic knowledge. One hundred and sixty medicinal and 75 non-medicinal plant-uses from 44 species were documented from 30 sample respondents. The average number of useful plants reported by healers and elders was expectedly higher (11.4 ± 4.19) than the knowledge of laypeople. Women were more knowledgeable in identifying the useful plants. When classifying 27 uses according to the level of species redundancy, we found that 20 uses were 'not very redundant', six 'redundant' and one 'highly redundant'.

Conclusion: Even though the life form and plant availability influence the plant use, the accessibility of habitats where the plant grow has stronger association with the plants' usefulness. The large number of 'non-redundant' uses indicates that plant use in study area is specific. The recent changes in socio-economy, culture, environment and land-use plague the conservation of plants resulting in jeopardy in integrity of plants, people and places.

Keywords: Useful plants; Ethnobotany; Culture, Availability; Kailash Himalaya

सार

पृष्ठभूमी : उपयोगीमुलक बिरुवाहरुको दिगो संरक्षणको लागी तिनको प्रकृति, फैलावट, बासस्थान, र साँस्कृतिक उपयोगीता र परिदृश्यका बारेमा अध्ययन गर्नु आवश्यक हुन्छ। हामीले तल्लो कैलाश पबित्र भूपरिधि क्षेत्रभित्रका जडिबुटीजन्य बिरुवाहरुको परम्परागत र साँस्कृतिक ज्ञानको संरक्षणमा कुन कुन तत्वहरुको भूमीका अहम् हुन सक्छ भनेर हामीले यहाँ अध्ययन गरेका छौं।

Correspondence

Ripu M. Kunwar[1,] Keshab Shrestha[2], Sulochan Malla[3], Tulasi Acharya[4], Arthur J. Sementelli[4]; Durga Kutal[5,*] and Rainer W. Bussmann[6]

[1]Ethnobotanical Society of Nepal, Kathmandu
[2]Natural History Museum, Tribhuvan University,
[3]Department of Biomedical Science, FAU, USA
[4]Department of Public Administration, FAU, USA
[5*]Wake Forest University, USA
[6]Ilia State University, Georgia, Orcid: 0000-0002-3524-5273 (rbussmann@gmail.com)
*Corresponding author: kutaldh@wfu.edu

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बिधि : बैतडी, डडेल्धुरा र दार्चला जिल्लाका ९ गाँउका कुल ६२ जना ६० बर्ष माथीका ४२ जडिबुटी संकलनकर्ताहरु र २० स्थानिय बैद्यहरु लगायतकाहरुको यो अध्ययनमा सहभागीता रह्यो । यस अध्ययनको लागी छानिएका ६२ सुचनादाताहरु स्नो बल नमुना छनोट प्रबिधि मार्फत पहिलो संकलनकर्ता र स्थानिय बैद्य पहिचान पछि उहाँहरुकै सहयोगमा पहिचान गरिएका थिए ।

नतिजाहरु : तल्लो कैलाश पबित्र भूपरिधि क्षेत्रका बैतडी, डडेल्धुरा र दार्चुला जिल्लाहरु जडिबुटीजन्य र उपयोगी बिरुवाहरु र तिनको परम्परागत र साँस्कृतिक उपयोगीतामुलक ज्ञानको हिसाबले धनी देखिन्छन् । अर्न्तवार्तामा कुल ३० अलि बढि जानकार सहभागीहरुले ४४ उपयोगी बिरुवाहरु पहिचान गरि तिनिहरुको १६० जडिबुटीजन्य र ७५ अन्य उपयोगहरुको बारेमा सुचना प्रदान गर्नु भएको थियो । प्रत्येक अलि बढि जानकार सहभागीहरुबाट प्रति बिरुवा सरदरमा ११.४ उपयोगहरु दर्ता गरियो । ति उपयोगहरु कुल २७ विविध प्रकारका थिए जसमध्ये २० प्रकारकाहरु बिरलैमात्र प्रयोग हुने खालका थिए भने ६ प्रकारकाहरु सामान्य प्रयोग हुने खालका थिए । बिरुवा पहिचान र तिनको घरायसी उपयोगमा महिला सहभागीहरु अलि बढि जानकार भएको पाईयो ।

निष्कर्ष : बिरुवाको उपयोगीता तिनको प्रकार र उपलब्धता सँगसँगै तिनीहरुसँगको पहुँचमा पनि भरपर्दो रहेछ । प्रशस्त बिरलै वा थोरै मात्र प्रयोगहुने खालका बिरुवाहरुको उपलब्धताले तल्लो कैलाश पबित्र भूपरिधि क्षेत्र बिरुवा उपयोग गर्ने संयन्त्रको हिसाबले बिशिष्ट छ भन्न सकिन्छ । सामाजिक अर्थ व्यवस्था, संस्कृती, वातावरण र भूमि उपयोगमा भईरहेका वर्तमान परिवर्तनहरु मानव, वोटविरुवा र वासस्थानको घनिष्टतामा बाधकसिद्द देखिन्छन् ।

Introduction

The holy mountain Kailash in the Western Himalaya represents the ultimate destination for millions of pilgrims of five religions – Hindu, Bouddha, Zain, Sikh and Bon (Zomer et al. 2013). The Kailash Sacred Landscape (KSL) is a collaborative trans-boundary and tri-national sacred landscape of Nepal, India and China to conserve ecosystem, biodiversity and culture of the region. Snow-capped areas and lakes of the landscape are valued as sacred sites and the alpine meadows, pastures and forests are treasured for transhumance, livestock grazing and collecting of high value medicinal plants like Himalayan caterpillar fungus - *Ophiocordyceps sinensis* (Berk.) G.H.Sung, Himalayan yew - *Taxus contorta* Griff., Love apple - *Paris polyphylla* Sm., etc. It is likely that those human communities that inhabit high altitude arid Himalayas use a large number of plant species (Salick et al. 1999). Many of the plants are collected and used for culture, livelihood and primary health care under the theoretical and practical traditional knowledge, mores and beliefs of surrounding health, illness and sociocultural values, and because of limited accessibility (Manzardo 1977, Kunwar et al. 2015).

There are three distinct physiographical regions in Nepal: lowland Tarai (< 700 m asl), hill (700-3,000 m asl) and mountain (3,000-8,848 m asl) (IUCN 2000). A steady pattern of migration from mountains and hills to the fertile Tarai is common. The shift was pronounced earlier (Goldstein et al. 1983). The tribal culture, language speaking and facial features of people of hills of Nepal provide the strong evidences of migration and human civilization from the north (Hagen 1961, Kawakita 1969). The migration from the north was meant to search of the best land for cultivation and grazing (Kawakita 1969). The migration routes via Urai, Bajhang; Lipulekh, Darchula and Hilsa-Taklakot, Humla (Shrestha 2001) are still popular today (Pandey 1989, Kunwar et al. 2018). The long history of a community's contact with nature translates into a tradition that integrates a high number of indigenous plants used for local livelihood (Prance 1972; Dalle & Potvin 2004). In addition, higher use values of plants were attributed to the cultural prominence of the species or to the long recognition of the particular species and its uses. Higher use values of plants also relate to their higher abundance in a given area and thus are more likely to be collected than the rarely encountered plants (Giday et al. 2003). Thus, we can assert that the factors associated with the usefulness of a plant species are sociocultural traditions and belief, ecological availability, and the geo-ecological complexities.

The identification, collection and use of plants vary on cross-cultural scales such as gender, age, ethnicity, occupation, population density, urbanization, migration, and labor mobility (Quinlan & Quinlan 2007). However, the indigenous systems of collection and use are affected by ecological and socio-cultural alterations (Saslis-Lagaudakis et al. 2014), and associated knowledge is often transformed (Winter & McClatchey 2008). Conservation of useful plants can be maintained and enhanced once complexities of a cultural landscape and knowledge, and principles of resource utilization are understood. While there have been efforts to document plant use in the KSL, the relevance of factors affecting such use is virtually unknown. In this study, we analyzed the importance of socio-culture, geography and plant availability (ecology) on collection and use of plants in the KSL, Nepal, to elucidate the better understanding of culture and conservation interactions. We hypothesized that plant collection and use is not random, and it is associated with the availability of plants, socio-cultural traditions and accessibility of sites.

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Materials and methods

Study area

This study was carried out in the Baitadi, Dadeldhura and Darchula districts (29º 01' N to 30º 15' N / 80º 15' E to 81º 09' E) of far western Nepal (Figure 1). Much of the study area consists of steep, semi-arid and rugged terrain, and only 7-21% are arable, resulting in limited access, food deficiency, and prevalent poverty often forcing people to either rely on local resources for subsistence, or to out-migrate (Kunwar et al. 2016). The Darchula district is the remote and least socio-culturally transformed area, originally known for growing Amaranth (Manzardo et al. 1976, Joshi 1981), and is a part of the relict hemp culture (Clarke 2007). A few remote villages of Dadeldhura district are occupied by the forest-dwelling Raute tribe, members of which live in and travel between the Siwalik hills in the south and mountainous highlands in the north, maintaining their livelihood by nomadic hunting and plant foraging (Fortier 2009). More than two thirds of the population rely on indigenous livelihood strategies such as animal husbandry, transhumance, seasonal crop production and collection, and the use and trade of medicinal plants (Manzardo 1977). The major castes of study area are Chhetri (>50%), Brahmin (20%), Thakuri (7%), Kami (10%) and Sarki (8%) (GoN 2014). Chhetri, Brahmin and Thakuri are relatively privileged groups with the highest well-being index (GoN 2014). Even though the Sarki and Kami (called as Dalit) are receiving reserved access and opportunities provided by the Nepal Government, they are still disadvantaged due to the socio-cultural and class system (Cameron 1998).

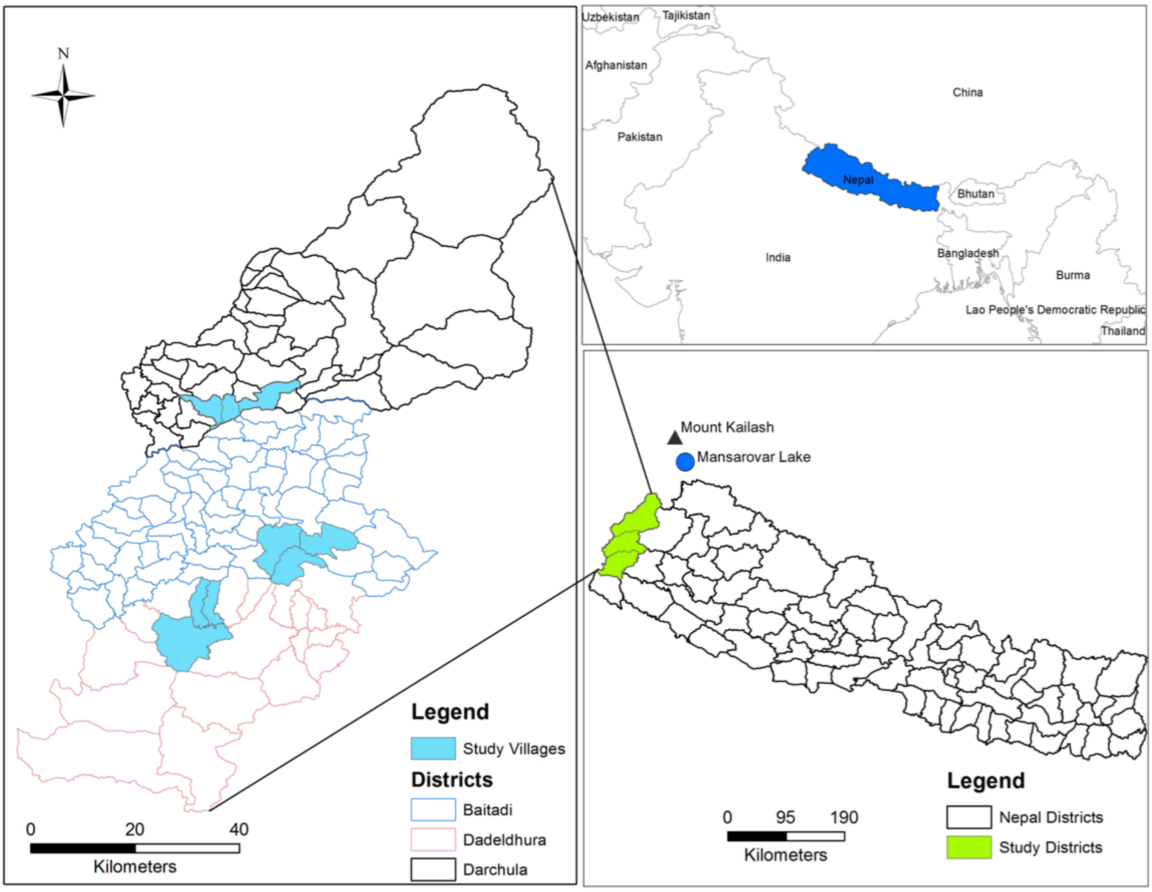

Figure 1. Map showing location of study area and sacred sites

During late 1970s, the government of Nepal forcibly resettled a group of Raute from northern Darchula to Dadeldhura district (Fortier 2009), deteriorating the integrity between forest and indigenous people. However, some local and indigenous forest management and religious fencings were in place in Byash, Huti and Pipalchauri (Darchula) (Chand & Wilson 1987) and Kotgaun, Salena and Binashaun (Baitadi) (Chhetri & Pandey 1992) to stop degradation. There are a number of commemorative pillars erected in about 1200 AD in Baitadi and Dadeldhura districts for memorializing the victorious warriors (Sharma 1997). The entirety of Kumaon Garhwal to Bairath (Baitadi), Doti, designated as the Katyuri kingdom under Nepal administration (Kumar 1967), was disintegrated in around 13th century and the Doti became the administrative center of far western Nepal and Kumaun Garhwal of India (Katoch 2010). Before the Anglo-Nepalese war (Gurkha War) of 1814-16, the corpus of feudal rites was considered a unifying aspect of culture of the area (Oakley & Gairola 1977).

Data collection

A 25-day field visit was made between December 2015 and January 2016 after establishing prior informed consent with the participants. Nine villages Bhadrapur, Chipur and Bagarkot of Dadeldhura, Gajari, Siddapur and Siddeswor of Baitadi, and Dethala, Bohorigaun and Gokuleswor of Darchula district were selected from 106 villages of three districts based on the consultations with district and local forest offices. A total of 62 respondents aged ≥ 60 years, including 42 plant collectors and 20 traditional healers of the subject villages were consulted for this survey following snow-ball sampling and based on village references. Once a traditional healer/plant collector was identified, snowball sampling helped locate and identify peer respondents.

Participants > 60 years were considered as knowledgeable (Mahwasane & Boaduo 2013) and selected for this study. A total of 46 aged between 64 and 96 years, including 20 traditional healers, agreed to participate and took part in interview. They mentioned a total of 515 use-reports from 170 (150 indigenous and 20 non-indigenous) useful plant species. Of 170 species, only 63 had ≥ 3 mentions each, resulting in 362 mentions. To avoid bias in the statistical analyses the data we used were limited to plant species with at least 3 mentions each, and respondents who contributed at least 3 citations of plant uses. Therefore, a data subset of 235 citations (160 medicinal and 75 non-medicinal) from 44 useful plants (42 indigenous and 2 non-indigenous) recorded from 30 active sample respondents (six women healers, 14 men healers and 10 men elders), was selected for further analyses (Supplementary file 1).

Conversations with healers and elders were based on a common objective: to increase knowledge regarding natural remedies and develop educational materials of local interest, as suggested in the guidelines of the International Society of Ethnobiology Code of Ethics (ISE 2008). Most of the plants mentioned in the interviews were collected in participatory walks and spot identified using vernacular names and ethnotaxonomic information and verified using secondary literature (Polunin and Stainton 1984). Plant vouchers and identifications were further confirmed and deposited at National Herbarium and Plant Laboratories (KATH), Nepal in 2016.

Data analysis

Species use-curve was used to assess whether the sampling intensity is adequate. The use-value, which is based on the number of uses and the number of people that cite a given plant, has been considered important within the ethnobotanical community. The use-value (UV) index adapted by Albuquerque et al. (2007) was used to calculate citation of plants during interviews as:

$$UVc = \sum U / ns$$

where U is the sum of the total number of use citations by all informants for a given species, divided by the total number of informants (ns). The sampling effort was tested by a Jackknife 1st order richness estimator 100 permutation species-use curve performed in R. Species-use curve was drawn from the cumulative number of species mentioned as being used versus the number of informants interviewed (Kristensen & Baslev 2003).

The Relative Importance Index (RI), indicative of the level of diversity of applications, was computed for each reported useful plants by using the formula based on (Bennett & Prance 2000):

$$RI = NP + NCS$$

where NP is obtained by dividing the number of properties (reported to be useful for specific uses) attributed to a species divided by the total number of properties attributed to the most versatile species (species with the highest number of properties). NCS is the number of individual uses treated by a given species divided by the total number of body systems (category of uses) treated by the most versatile species.

The Factor of Informant consensus (Fic) has been determined to identify the most potential medicinal plant species used in study area:

$$Fic = Nur – Nt / Nur –1$$

where Nur is the number of mentions from informants for a particular ailment category, Nt is the number of taxa that are used for the ailment category. Fic value ranges between 0-1, where a

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high value indicates the greater informant consensus and a lower value signifies disagreement among the informants. Each use was classified according to its level of species redundancy: highly redundant (≥ 15% species employed to use that particular type), redundant (15% < number of species ≥ 5%), and not very redundant (number of species < 5%) following Albuquerque & Oliveira (2007). Five categorical variables (gender, age group, ethnicity, experience and district) were used to assess the indigenous knowledge of local people by using t-test and one-way analysis of variance (ANOVA) at 95% confidence level between means.

Results

Useful plants and informant consensus

Our results show that three study districts Baitadi, Dadeldhura and Darchula are rich in useful plant species and a wealth of traditional knowledge. Among the 44 (43 plants and 1 product), 15 were trees, 13 shrubs, 12 herbs and 4 others (climbers, epiphytes, rock exudate). They represented 33 families, of which Meliaceae and Fabaceae were the dominant families, each contributing 3 species. The average citation for each respondent was 7.8. The mentions were categorized into 27 uses (17 medicinal and 10 non-medicinal). The medicinal uses were categorized into 11 disease categories following Phillips & Gentry (1993). Non-medicinal uses were grouped into 7 categories (Table 1).

Eight different species were used for cough and cold followed by four for muscle and joint pain. Respiratory system disorders (cough and cold) were treated folkloric by using the greatest number of redundant species (8), followed by the utilization of seven species for treatment of musculo-skeleton system disorders (joint pain, fracture, and sprain) and five species for infection (cuts and wounds) as well as for fever. Digestive, ophthalmic and nervous system disorders were treated by three species each (Table 1).

Table 1. Informant consensus (Fic) and redundancy values

Use category	Body system and use types	Total mentions	Species used	Consensus (Fic)	Redundancy (%)
Medicinal	Respiratory System (RES) - Cough & cold	35	8	0.79	18.18
	Musculo-Skeletal System (MSK) - Fracture and joint pain	32	7	0.80	15.90
	Infections (INF) - Fever, cuts and wounds	26	5	0.84	11.36
	Digestive (DIG) – Stomachache	13	3	0.83	6.81
	Poisonous (POS) – Antidote	6	2	0.80	4.54
	Opthalmic (OPTH) - Eye complaint	9	3	0.75	6.81
	Cardio Vascular System (CVS) -Vein disorder	6	2	0.80	4.54
	Nervous System (NVS) - Memory longevity	3	1	1.00	2.27
	Dentist (DENT) - Toothache	3	1	1.00	2.27
	Dermatory System (DERM - Skin diseases	12	3	0.82	6.81
	OTHERS - Lactation, thorn remover	15	2	0.93	4.54
Non-medicinal	Edible	6	2	0.80	4.54
	Fishing	30	5	0.86	11.36
	Fibre, Rope	10	2	0.89	4.54
	Fodder	3	1	1.00	2.27
	Dye	3	1	1.00	2.27
	Timber, log, stick, pots	17	4	0.81	9.09
	Vegetable, spices	6	2	0.80	4.54
Total		235	44		

Our study found that there was a high level of consensus among the informants regarding treatment of illnesses and medicinal plant use. The informant consensus (Fic) value for different uses ranged from 0.75 to 1.00, which indicates a high agreement among the informants regarding usefulness of a plant. Fic was used to highlight plants of particular cultural relevance and agreement in the use of plants. The highest degree of consensus (1.0) for the use of *Centella asiatica* (L.) Urb. for memory longevity, *Vitex negundo* L. shoots for toothache, *Melia azedarach* L. as fodder and *Myrica esculenta* Buch.-Ham. ex D. Don as dye plant showed that consensus was for ethnomedicine through

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sociocultural values (Table 1). The categories respiratory and ophthalmic, some medicinal uses (cough and cold, eye complaint), and non-medicinal uses (edible, vegetable and spices) represented the least consensus values (0.75-0.80). Plants with high Fic are likely to be more pharmacologically efficient as compared to plants with low Fic (Heinrich 2000). If there will be a number of species with redundant utilities, a particular use type will have low Fic. The use with low Fic value is random and less credible.
There was a significant difference ($p < 0.01$) in the number of medicinal plants reported by healers and elders. The average number of plants reported by healers was 11.4 whereas the same of elders was 4. The difference was also significant ($p < 0.05$) at district level (Table 2). However, there was no significant difference in the knowledge of useful plants among the ethnic groups, gender and age group (Table 2). Although 10.33±4.36 plants were reported as useful by women than men 8.58 ± 4.97, the difference was not significant ($p > 0.05$) when the average number of plants reported by each group was compared. Age-group wise analysis also did not reveal a significant difference in their response, even though the 80-89 years group was more knowledgeable, each respondent mentions 9.66 ± 5.85 plants.

Table 2. Statistical analyses of number of useful plants at different variables.

Parameters	Participant detail	N (30)	Average and Std. Dev.	*p*-value	t-value
Gender	Men	24	8.58±5.15	Ns	Ns
	Women	6	10.33±4.36		
Age group (years)	60-69	14	8.85±4.97	Ns	
	70-79	11	8.90±5.33		
	80-89	3	9.66±5.85		
	90 ≤	2	8.50±6.36		
Experience	Healers	20	11.4±4.19	< 0.01	< 0.01
	Elders	10	4.0±1.41		
Ethnicity	Brahmin	10	8.0±5.01	Ns	
	Kshetri	17	9.94±5.27		
	Disadvantaged	3	6.33±0.57		
District	Dadeldhura (1560 m)	15	7.26±4.19	< 0.05	
	Baitadi (1565 m)	7	6.57±2.57		
	Darchula (2060 m)	8	14.12±5.02		

Ns = Non significant

Species-use curve

The species-use curve approached an asymptote as the number of interviews increased. This indicated that further sampling of respondents would not yield new species. No further species were added after the 24th interview ($p = < 0.05$) (Figure 2). The curve was an asymptote from the 17th respondent if we considered only healers as respondents. Conversely, the curve did not level off for elder respondents, thus a greater number of elder participants were required in order to attain the sampling asymptote.

Use-Value and Relative Importance

The use-value was highest (0.66) for *Agave cantula* Roxb. for fishing, *Euphorbia royleana* Boiss. milk for its topical use in joint pain and eye trouble (0.46), rhizome of *Bergenia ciliata* Sternb. for stomachache (0.33), *Ageratina adenophora* (Spreng.) R. M. King & H. Rob.) for bleeding control and cuts and wounds (0.3), milk of *Ficus palmata* Forssk. as thorn remover (0.3). The relative importance index (RI), indicative of the level of diversity of applications, was computed for each reported useful plant. The plants *Agave cantula* (0.098), *Euphorbia royleana* (0.081), *Bergenia ciliata* (0.076), *Scurrula elata* (Edgew.) Danser (0.070) and *Myrica esculenta* (0.68) were useful for two or more purposes. Three species *Agave cantula, Euphorbia royleana,* and *Bergenia ciliata* were found as most useful in both indices. Out of 10 important useful plants, two species *Agava cantula* and *Ageratina adenophora* were non-indigenous. Relative importance value was higher for herbs however there was no statistical difference among the life form variables ($p = 0.46$). The average use value of physically apparent plants (trees and shrubs) 0.17 was comparable to that of herbs (0.19) (Figure 3).

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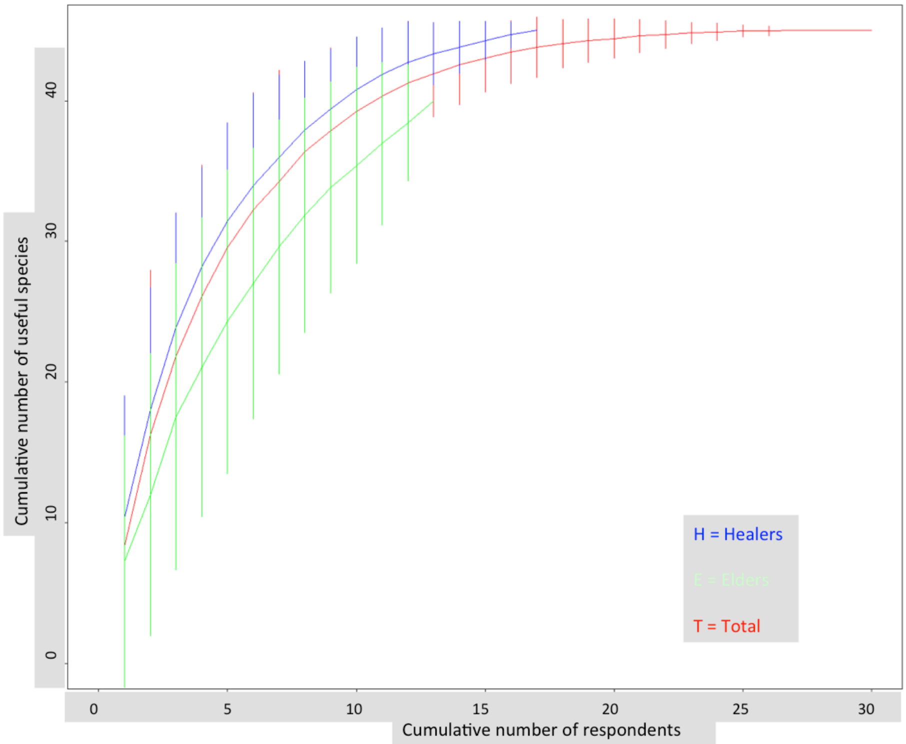

Figure 2. Species-use curve showing the importance of number of respondents in documenting the useful plant species

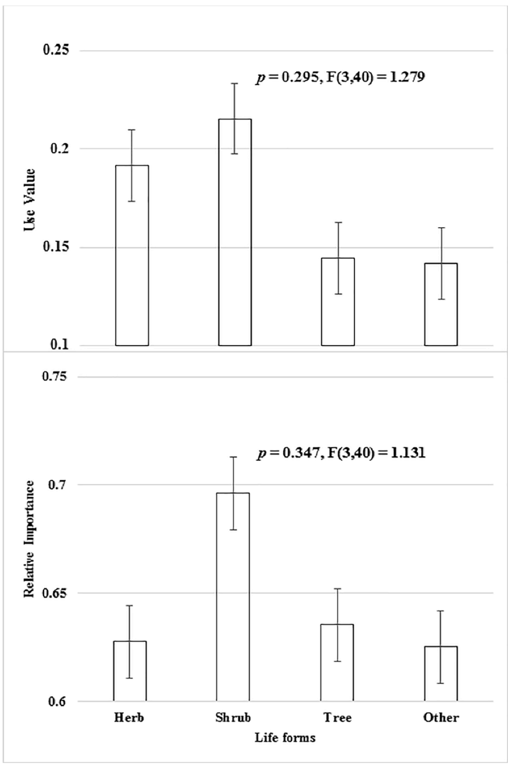

Figure 3. Statistical significance of plant form, use values (UV) and relative importance (RI)

Discussion

Our findings are consistent with those of Singh et al. (2012) and Rashid et al. (2015), who recognized that trees were among the most significant plant forms for ethnomedicine in the Himalaya. Trees persist throughout the year and serve as constant source for folk medicine (Voeks 2004). Trees, woody and perennial plants are apparent and most important medicinal resources in the Brazilian semiarid region (Almeida et al. 2005), and they produce high secondary metabolites while defending themselves from consumers (Albuquerque & Lucena 2005). The importance of trees of Meliaceae and Fabaceae as ethnobotanical was also cited by Fasola (2015) and Noel et al. (2016). Meliaceae is said to accumulate bitter and biologically active nortriterpenoids (limonoids and meliacins), showing antifungal (Engelmeier et al. 2000) and antibacterial effects (Aboutable et al. 2000). *Azadirachta indica* A. Zucc. (Meliaceae) folkloric for skin disease is accorded to the discussion.

The average use value of apparent plants: trees and shrubs ranged between 0.17±0.12 was comparable to use values of herbs (0.19±0.06) (p = 0.295) (Figure 3). According to Phillips & Gentry (1993), apparent plants are expected to feature more

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strongly in local botanical knowledge, i.e. the largest, most dominant, and most frequent plants should have the highest use values, not because they are necessarily and intrinsically more useful, but simply because they are available, distinct or visible to human communities (Thomas et al. 2009). However, we found that the most apparent trees did not associate with higher use values, which is similar to that observed by Cunha & Albuquerque (2006). This was attributed to the fact that plant use values sometimes correlate with the issues of plant conservation. The most important species are often suffered from the greatest harvesting pressure (Albuquerque et al. 2007). Herbs (non-apparent plants) on the other hand invest in qualitative defenses, employing extremely active compounds occurring at low concentrations (Albuquerque & Lucena 2005). Relative importance value was higher for herbs (p = 0.46). High RI value could partly be a reflection of abundance as medicinal plants that are found in plenty in a given area are more likely to be favored for collection than those that are encountered rarely.

High versatility of medicinal plants could also indicate a higher diversity of active compounds contained in the species. Weeds are now amply represented in folk medicines because they are growing abundantly at ruderal and secondary habitats, are easy to harvest, and are frequently rich in bioactive compounds (Stepp & Moerman, 2001). We consistently observed that people preferred to collect plants that were easily harvested nearby. It was found that such plant collecting gave less consideration to quality (Harlan 1992) and more importance to subsistence, time, accessibility and familiarity. Our data evidenced that, even when plant apparency and availability (i.e. the environment) are always important, the geography and cultural environment (accessibility, familiarity, important for livelihood and the least time consumption for extraction) have the strong influence on the use of medicinal and edible plants in rural communities. Weckerle et al. (2006) and Saslis-Lagaudakis et al. (2014) found that geography and culture seem to have greater influence on plant uses in mountainous areas.

Status of knowledge

The significant difference ($p < 0.05$) on average number of plants reported by healer and elders showed that the indigenous knowledge is, like in many places, concentrated in healers (11.4±4.19). Other studies show the significant difference between age-groups on knowledge of useful plants (Estomba et al. 2006) but that knowledge of number of medicinal plants found in the present study was homogenous and statistically insignificant, consistent to Ladio & Lozada (2004). This could be attributed to the (non-random) selective sample size (> 60 years) and unwillingness to share information by elderly people. The secrecy of medicinal plant knowledge is a common practice in different parts of the world (Kala 2006). The age group 65-75 held a greater range of knowledge (Figure 4), which is consistent with the findings of Mahwasane & Boaduo (2013).

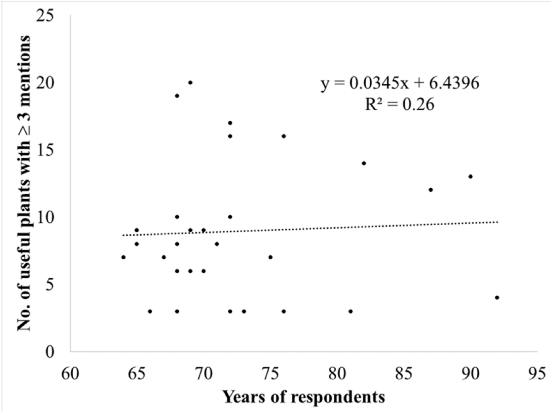

Figure 4. Pattern of plant use knowledge according to the age of respondents

The species-use curve for both (healers and elders) respondents approached an asymptote from the 25th candidate and indicated that further sampling of respondents would not yield the new information of useful species. This is consistent with the underlying hypothesis that a limited number of species were used, and that the most salient species can be elicited after a limited number of in-depth interviews. As sampling effort increases, more elders were encountered, and more species are likely to be recorded. Thus, if we consider elders as sample respondents for ethnobotanical studies, a greater number of sampling is required in order to find the statistically significant values (Heck et al. 1975). The greater knowledge of older people on plants is the result of high degree of opportunity for more cultural contact and experience with plants and associated therapeutic uses than that of younger people (Joshi et al. 2015). A continuous outmigration for menial work in India (Poertner et al. 2011) and a greater percentage of absentee population 7.51% than the national average 7.23% clearly drove a decline in the number of healers and indigenous knowledge in the studied district. Outmigration to urban areas and low lands results in abandonment of rural hilly areas jeopardizing the sustainable land use system. Decreasing knowledge of indigenous species aids incentives to non-indigenous resources introduction. The land tenure system though instrumental in past in making a strong bond between landholders and

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labors/tenants following caste lines, culture and land-use management regimes is obsolete at present in the changed population, land availability, and sociocultural traditions. This change has disenfranchised the lower/disadvantaged groups who have less land-holding and led them to work off-farm and non-indigenous businesses.

Collection and conservation

Thanks to the difficult access, much traditional knowledge of useful plant species is still thriving with the indigenous people at high altitude areas like Darchula (14.12±5.02). Our results are consistent with the finding of Byg et al. (2010), reporting that people at higher elevation villages have known and used more medicinal plants than people in lower villages. Distant and undisturbed areas were often cited by traditional healers as refuges for quality products. Similar reports were found in adjoining areas of India (Garbyal et al. 2005, Malik et al. 2015) and other parts of the world (Adnan & Holscher 2011) where a higher number of indigenous species with medicinal usage are being used at remote and higher altitudes. The important motivation for foraging at distant wild forests is to obtain high quality products as Schunko et al. (2015) described. However, many plant species and populations and habitats that have long been considered to be wild are actually carefully nurtured by people, albeit less intensively. Thus, the forests and landscapes of Kailash can be considered as social space and human cultural artifacts.

A large number of trees extracted for ethnomedicine from distant areas were found to correlate with men participants. Women knew more about local plants growing in nearby areas and forests to home (Coe & Anderson 1996). However, we did not see any relationship of higher extraction of weedy and annual herbs from nearby areas by women. Women were found to report more useful plants on average (10.33±4.36) than men (8.58±5.15) even though the difference was not statistically significant ($p = 0.45$). The knowledge of medicinal plants also revealed the similar trend (women 7.66±2.65; men 5.33±3.65, p = 0.15). Generally, gender based differences in medicinal plant knowledge can be derived from experience and degree of cultural contact with plants.

The acceptance of non-indigenous resources like weeds in ruderal areas following the tenet of availability and familiarity refutes the cultural values and indifference to therapeutic potentialities of plants. Species introduction for specific purpose, first by indigenous and later by diaspora communities, could be a potent cause of transformation of indigenous systems. The institutionalization of non-indigenous resources to indigenous systems becomes germane once the resources are used cautiously and as compliments to indigenous medicine, and the whole process is considered as a part of adaptation (Scott 2008). Ladio & Lozada (2004) found a situation, in which a community extracted a higher percentage of food plants in the vicinity of residences. Rugged and less accessible areas are often a source of quality medicinal plant products (Kala 2006, Kunwar et al. 2018).

When classifying 27 uses according to the level of species redundancy, it was found that 20 uses were not very redundant, six redundant and one (cough and cold) highly redundant. Similar observation of highly redundant therapeutic functions of species useful in cough was observed by Albuquerque & Oliveira (2007). The high redundancy found, e.g. 35 mentions and eight species used only for cough and cold (respiratory body system), may result from the large number of bioactive compounds of those species that can treat that body system, as found by Medeiros & Albuquerque (2013). The high use of medicinal plants to cure respiratory complaints could be attributed to the high preponderance of that ailment in the area. In other villages of study area, a high number of medicinal plants were found to cure stomachache (digestive disorder) (Kunwar et al. 2015). According to the utilitarian redundancy model, higher numbers of redundant utilities will correlate with higher degrees of system flexibility and, consequently, of system resilience. Despite the high species richness of useful medicinal plants, a larger proportion of species did not share the same function, which indicates a high degree of specialization in plants used for treating local illnesses.

Conclusions

The average use value of apparent plants (trees and shrubs) 0.17±0.12 was comparable to that of herbs (0.19±0.06). It was found that 20 out of 27 uses were 'not very redundant'. Higher numbers of redundant utilities correlate with higher degrees of system flexibility and, consequently, of system resilience. However, the changes in socio-economy, culture, forest cover and land-use also press the population to use non-indigenous resources. This indicates the dynamism of indigenous resources and knowledge, leaves ground for institutionalization, and is considered as an asset of adaptation once the resources are used cautiously and as compliments. The distribution of the knowledge of useful plants is not uniform within a population, and that the patterns can be better understood when geographical, cultural, historical, and environmental factors are considered.

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Declarations

Ethics approval and consent to participate

Before conducting interviews, prior informed consent was obtained from all participants. No further ethics approval was required.

Consent for publication

This manuscript does not contain any individual person´s data and further consent for publication is not required.

Availability of data and materials

Additional file contains data. Other data contain the names of all participants and cannot be shared in this form.

Declaration of interests

The authors declare that they have no competing interests.

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Author contributions

RK, SM, TA and AS designed the study; RK and KS conducted the fieldwork and data collection; DK and RB conducted the main statistical analysis; RK, SM and TA analyzed the data and wrote the manuscript; and all authors read, corrected and approved the manuscript.

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Supplementary file 1. List of useful plants and products, citations, use value and relative importance

Scientific name (Col. #)	Family name	Local names	Life forms	Total citations	Citations for statistical analysis	Use Value	Relative Importance
Agave cantula Roxb.	Agavaceae	*Ram bans*	S	20	20	0.66	0.78
Centella asiatica (L.) Urb. (6-06)	Apiaceae	*Khochadey*	H	9	6	0.20	0.68
Carum carvi L. (Schmidt 2949)	Apiaceae	*Kal jeera*	H	8	6	0.20	0.59
Acorus calamus L. (176-06)	Araceae	*Bojho*	H	6	4	0.13	0.59
Ageratina adenophora (Spreng.) R. M. King & H. Rob.(Abott12931)	Asteraceae	*Banmara*	H	9	9	0.30	0.59
Artemisia indica Wall. Ex Besser (7214)	Asteraceae	*Kurjo*	S	8	5	0.16	0.59
Berberis asiatica Roxb. ex DC. (34-06)	Berberidaceae	*Kirmada*	S	7	6	0.20	1.09
Oroxylum indicum (L.) Kurz. (7238)	Bignoniaceae	*Tata, Faltate*	T	6	3	0.10	0.59
Valeriana jatamansii Jones (84-06)	Caprifoliaceae	*Simme*	H	6	4	0.13	0.59
Terminalia chebula Retz. (68-06)	Combretaceae	*Harro*	T	5	5	0.16	0.59
Cuscuta reflexa Roxb. (7265)	Convolvulaceae	*Akasbeli*	O	4	3	0.10	0.59
Shorea robusta Gaertn.	Dipterocarpaceae	*Sal*	T	6	6	0.20	0.64
Euphorbia royleana Boiss.	Euphorbiaceae	*Suido*	S	14	12	0.46	0.68
Sapium insigne (Royle) Benth. & Hook. f. (53-06)	Euphorbiaceae	*Khirro*	T	8	6	0.20	0.64
NOT IDENTIFIED	Fabaceae	*Irru*	O	4	4	0.13	0.64
Indigofera heterantha Wall. ex Brandis (113-15)	Fabaceae	*Sakhino*	S	3	3	0.10	0.64
Abrus precatorius L. (7209)	Fabaceae	*Rati gedi*	S	4	3	0.10	0.59
Quercus lanata Sm. (197-15)	Fagaceae	*Banjhkhar*	T	7	6	0.20	0.68
Swertia racemosa (Wall. ex Grieseb.) C.B. Clarke (202-15)	Gentianaceae	*Tite*	H	8	6	0.20	0.59
Engelhardia spicata Lesch. ex Blume (Cuong 179)	Juglandaceae	*Mouwa*	T	4	4	0.13	0.64
Pogostemon benghalensis (Burm. f.) Kuntze (11-15)	Lamiaceae	*Rudro*	S	3	3	0.10	0.59
Vitex negundo L. (7302)	Lamiaceae	*Syali*	S	3	3	0.10	0.59
Cinnamomum tamala (Buch-Ham.) T. Nees & Nees(7215)	Lauraceae	*Dalchini*	T	3	3	0.10	0.64
Paris polyphylla Sm. (7256)	Liliaceae	*Satuwa*	H	8	6	0.20	0.68
Asparagus racemosus Willd. (6-15)	Liliaceae	*Jhirjhirine*	H	6	6	0.20	0.59

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Scurrula elata (Edgew.) Danser (150-15)	Loranthaceae	*Lisso*	O	9	7	0.23	0.68
Grewia optiva Drumm. ex Burret(Bodner 241)	Malvaceae	*Vyul*	T	3	3	0.10	0.64
Cedrela toona (Roxb. ex Rottler & Willd.	Meliaceae	*Toodi, Tooni*	T	4	3	0.10	0.64
Melia azedarach L. (WB 115)	Meliaceae	*Bakainu*	T	3	3	0.10	0.64
Azadirachta india A. Juss.(Schmidt 3151)	Meliaceae	*Neem*	T	3	3	0.10	0.59
Ficus palmata Forssk. (153-15)	Moraceae	*Bedu*	S	10	9	0.30	0.59
Myrica esculenta Buch.-Ham. ex D.Don. (567-00)	Myricaceae	*Kafal*	T	6	6	0.20	0.78
NOT IDENTIFIED	NOT IDENTIFIED	*Gaarudi*	S	4	3	0.10	0.59
Cyanodon dactylon L. (Anderson 85)	Poaceae	*Dubo*	H	4	3	0.13	0.68
Rock exudate	Rock exudate	*Silajit*	O	4	3	0.10	0.59
Rubus cordifolius Weihe & Nees (183-15)	Rosaceae	*Aisedu*	S	14	6	0.20	1.09
Pyracantha crenulata (D. Don.) M. Roem.(173-15)	Rosaceae	*Gangaru*	S	5	4	0.13	0.64
Zanthoxylum armatum DC. (69-06)	Rutaceae	*Timur*	S	6	5	0.16	0.59
Sapindus mukorossii Gaertn.(7257)	Sapindaceae	*Rittha*	T	7	6	0.20	0.59
Madhuca indica J. F. Gmel.	Sapotaceae	*Kalchiuri*	T	5	4	0.13	0.59
Bergenia ciliata Sternb. (124-06)	Saxifragaceae	*Bhedaite, Silphode*	H	16	10	0.33	0.68
Urtica dioica L. (7290)	Urticaceae	*Sisno*	H	6	6	0.10	0.68
Debregesia longifolia (Burm. f.) Wedd. (Heng 8548)	Urticaceae	*Githi*	T	5	4	0.13	0.64
Curcuma angustifolia Roxb. (7259)	Zingiberaceae	*Haldi*	H	8	5	0.16	0.59

H = Herb, S = Shrub, T = Tree, O = Others

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