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Medicinal plant diversity and traditional healing practices in eastern Nepal

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ABSTRACT

Ethnopharmacological relevance: The rich floral and ethnic composition of eastern Nepal and the widespread utilization of locally available medicinal plants offer remarkable opportunity for ethnomedicinal research. The present paper aims to explore medicinal plant diversity and use in the remote villages of eastern Nepal. It also aims to evaluate ethnopharmacological significance of the documented use reports and identify species of high indigenous priority.

Materials and methods: The study was undertaken in four villages located in the Sankhuwasabha district in eastern Nepal. Ethnomedicinal information was collected through structured interviews. The homogeneity of informant's knowledge and the relative importance of documented medicinal plants were validated by informant consensus factor and use value, respectively. Species preference for treatment of particular diseases was evaluated through fidelity level.

Results: We reported medicinal properties of 48 species belonging to 33 families and 40 genera, for the treatment of 37 human ailments. The uses of 10 medicinal plants were previously undocumented. The informant consensus factor (F_{IC}) ranged between 0.38 and 1 with about 50% of values greater than 0.80 and over 75% of values greater than 0.70, indicating moderate to high consensus among the informants on the use of medicinal plants in the region. *Swertia chirayita* was the most preferred species with significantly high use values, followed by *Paris polyphylla* and *Neopicrorhiza scrophulariiflora.*

Conclusions: The remote villages in eastern Nepal possess rich floral and cultural diversity with strong consensus among informants on utilization of plants for local healthcare. The direct pharmacological evidence for medicinal properties of most species indicates high reliability of documented information. Careful and systematic screening of compounds isolated from these plants could possibly provide good opportunity for the discovery of novel medicines to treat life-threatening human diseases. We recommend prioritization of medicinal plants and reinforcement of existing cultivation practices for sustainable management of high-priority species.

1. Introduction

The investigation of plants for their use in medical treatment has been practiced by many cultures throughout history. Given their extensive range of knowledge on medicinal plants utilization, indigenous people remain the ultimate source for retrieving this information for the purpose of application, particularly in modern medicines (Idu, 2009). Ethnobotanical investigations in the past have led to the development of important anti-cancer drugs such as *podophyllotoxin* (Imbert, 1998) and *reserpine* (López-Muñoz et al., 2004) as well as drugs such as *vinblastine* (Raviña, 2011) to treat hypertension. However, in absence of proper documentation, many traditional methods and general knowledge of medicinal flora is being lost. In addition, many useful species are being wiped out from their natural habitats due to increasing anthropogenic pressure, and consequently, certain medicinal traditions are at risk of extinction (Shrestha et al., 2014).

Nepal is an excellent repository of cultural heritage and the use of plants as folklore medicines has been practiced since the beginning of human civilization. Local plant-based therapy is a

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common practice in the rural communities of Nepal (Manandhar, 1998). While this is not only medical options available, most communities lack direct access to modern medicine and it is estimated that about 80% of the population depends upon herbal medicines (Rajbhandari and Bajracharya, 1994). Approximately 1700 species of flowering plants are currently being utilized as medicines in Nepal (Baral and Kurmi, 2006) and the number is expected to grow as infrastructure allows greater access to unexplored parts of the country. Ethnobotanical studies in the past have focused more on the Himalayan districts of western and central Nepal (Joshi and Edington, 1990; Manandhar, 1998; Shrestha and Dhillion, 2003; Bhattarai et al., 2006; Kunwar et al., 2006; Rokaya et al., 2010; Uprety et al., 2010; Luitel et al., 2014; Shrestha et al., 2014) whereas the ethnomedicinal documentation from eastern Nepal is relatively sparse.

Tinjure-Milke-Jaljale (TMJ), commonly known as Rhododendron Conservation Area, represents an important habitat in East Nepal, encompassing two major ecoregions: (1) Eastern Himalayan alpine shrubs and meadows and (2) Eastern Himalayan broad-leaved forest. This small area (585 km^2) harbors about 250 species of flowering plants with 17 endemic, 9 endangered and 14 threatened species (IUCN Nepal, 2010). The area has a mixed cultural setting with people from various ethnic groups (*Rai*, *Limbu*, *Chhetri*, *Brahmin*, *Sherpa*, *Tamang* and *Gurung*). The utilization of medicinal and aromatic plants (MAPs) is a common practice among the local inhabitants. The majority of these species have high commercial value and a large proportion of them enter domestic and international markets through legal as well as illegal routes.

Previous studies from the TMJ area have mainly focused on enumeration of angiosperm flora (Ohba and Akiyama, 1992; Limbu et al., 2012a) and rangeland weeds (Limbu et al., 2012b). Although ethnobotanical studies exist for regions around the TMJ area (eg. Rai, 2003; Gautam, 2011), they were mere enumerations and therefore, lack significant utility for ethnobotanical research. At present, information on the number of medicinal plants growing within the TMJ area, particularly Sankhuwasabha district, and knowledge on their therapeutic potential are largely inadequate. The only ethnobotanical study from Sankhuwasabha district is that of Parajuli (2000). However, he focused on only one municipality from the district. A larger part of this district, especially areas lying within the TMJ are yet unexplored. Therefore, with an aim to explore ethnomedicinal practices in the culturally and biologically rich mountainous landscape of eastern Nepal, we have undertaken this study in four major Village Development Committees (VDCs) of Sankhuwasabha district lying within the TMJ area. Specifically we aim to (a) explore the diversity of plants used in *Nundhaki, Madimulkharka, Tamafok* and *Mawadin* VDCs of Sankhuwasabha district, (b) estimate variability in the use of medicinal plants with comparison to existing literature, (c) evaluate informant consensus on the use of plants for medical purposes, (d) identify preferred species of medicinal plants and (e) evaluate if knowledge on medicinal plant utilization varies with age and ethnicity.

2. Materials and methods

2.1. Study area

The TMJ area lies between 27°6′57″ to 27°30′28″ N latitude and 87°19′46″ to 87°38′14″ E longitude, covering an area of about 585 km^2 of three districts: Sankhuwasabha, Terhathum and Taplejung in the Eastern Development region of Nepal (Fig. 1; IUCN Nepal, 2010). The area covers 7 Village Development Committees (VDCs) of Sankhuwasabha, 10 VDCs of Terhathum and 6 VDCs of Taplejung.

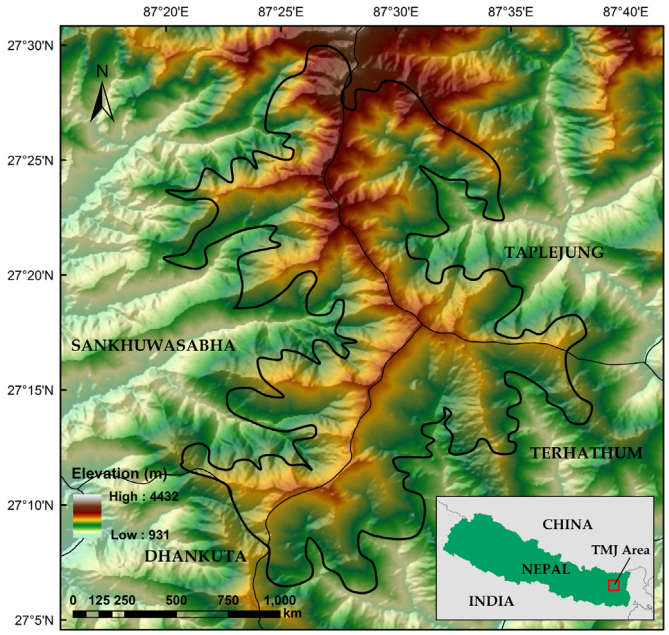

Fig. 1. Map of Tinjure-Milke-Jaljale (TMJ) area in eastern Nepal.

The area falls under the lesser Himalaya and represents a high degree of variation in topography within an elevation range of 1700–5000 m. The greater part of the area (43%) has moderately sloped (5–30°) terrain. More than 26% of the area has steep slopes with an inclination of about 30–40° and the remaining 31% has very steep slopes with inclination greater than 40°. The climate ranges from warm temperate in the lower region followed by cool temperate in the mid-hills to alpine in the upper hill slopes. Precipitation varies from 1000 to 2300 mm; the average rainfall is about 1650 mm (IUCN Nepal, 2010). We conducted our study in 4 major VDCs: *Nundhaki, Madimulkharka, Tamafok* and *Mawadin* of the Sankhuwasabha district lying within the TMJ area.

2.2. Data collection

We followed ethical guidelines adopted by the International Society of Ethnobiology (ICE) and carried out interviews and field observations based on standard ethnobotanical methods (Martin, 1995; Alexiades, 1996; Cotton, 1996). We obtained prior informed consent from the local people verbally before we interviewed them. We met the local people and community leaders and clearly outlined them the purpose of our visit and the intent of our research. We initiated data collection only after receiving verbal approval from them. We employed random and snowball sampling techniques to identify potential participants and interviewed a total of 59 people (47 men and 12 women) between the ages of 25–75 years. The respondents included individuals from various ethnic and socioeconomic backgrounds, including local faith healers, medicinal plant collectors, medicinal plant cultivators, traders and knowledgeable community members. The majority of respondents were *Sherpa* (31%), followed by *Chhetri* (30%), *Brahmin* (17%), *Limbu* (10%), *Tamang* (10%) and *Gurung* (2%). Eighty percent (80%) of the respondents were fairly literate (just able to read and write), 8% had no formal education, 10% had secondary school education and only 2% had higher education.

We used *Nepali* language to interview local people, since it was the commonly understood language in the study area. In some cases, we sought the help of a local translator to communicate with *Sherpa* people. Structured interviews were conducted to collect information on the use of plants, including the parts used, mode of preparation and administration. We first conducted

interviews using the 'specimen display' method. After collecting plant specimens, we showed the specimens to the locals in order to gather information about their medicinal use. The same plant specimens were shown to different people to confirm the reliability and validity of the information. Next we asked some of our participants to accompany us to the medicinal plant distribution sites, and information was collected therein. A consensus list of medicinal plants was prepared based on agreement in medicinal plants use cited by local people. All the reported ailments were grouped under 14 categories (see Table 2 for details) depending upon their relatedness to treating ailments of particular systems and/or organs of the human body. These categories were cancer, cardio-vascular disorders, cough and cold, cuts and wounds (including burns), dermatological infection, gastro-intestinal disorders, gynecological disorders, headache/fever, neurological disorders, respiratory disorders, skeleto-muscular disorders, tonic/stimulant, tooth and gum problems and worm infection.

2.3. Identification of plants

Plants were surveyed from *Chauki, Ghurbise, Guphapokhari, Jorpokhari, Laampokhari, Mangalbare, Paanchpokhari, Sukebazar* and *Tinjurephedi* of four VDCs in the Sankhuwasabha district. Common species which were easily identifiable in the field were not collected. The localities of these species were recorded and photos were taken for reference. For those species which could not be directly identified in the field, high resolution photographs of whole plants, flower, fruits, leaves, etc. were taken along with field notes. These species were identified later using standard botanical literatures widely used to identify flowering plants in Nepal (eg. Hara et al., 1978, 1982; Hara and Williams, 1979; Grierson and Long, 1983–2001; Polunin and Stainton, 1987; Stainton, 1988; Shrestha and Joshi, 1996). We followed the nomenclature of Press et al. (2000) as it is the most recent checklist of flowering plants in Nepal. The species names and families were finally updated using the PlantList database available online at www.theplantlist.org (Accessed: Dec 12, 2015).

2.4. Data analysis

2.4.1. Informant Consensus Factor (F_{IC})

By adopting the method originally developed by Trotter and Logan (1986), we calculated informant consensus factor (F_{IC}) in order to validate the homogeneity of informant's knowledge. It was calculated as:

$$F_{IC} = N_{ur} - N_t / (N_{ur} - 1)$$

where N_{ur} is the number of use reports in each ailment category and N_t is the total number of taxa used in each ailment category. F_{IC} is generally calculated to evaluate agreement between informants in the use of plants for a particular ailment category. Its value ranges between 0 and 1. High F_{IC} values are obtained when only one or a few plant species are reported to be used by a high proportion of informants to treat a particular ailment, whereas low F_{IC} values indicate that informants disagree over which plants to use (Heinrich et al., 1998). The consensus method helps us to identify important and interesting species for further cultural and pharmacological research (Treyvaud et al., 2005).

2.4.2. Use value (UV)

The relative importance of a plant species used as medicine in the study area was calculated with the use value (Phillips et al., 1994) from the following formula:

$$UV = \sum U / N$$

where U is the number of use reports cited by each informant for a given plant species and N is the total number of informants interviewed for a given plant species. High use value denotes high use for a particular plant and low use value indicates that the plant has few use reports and therefore is less preferred in the study area.

2.4.3. Fidelity level (FL)

The most preferred species used in the treatment of particular ailment category was determined by using fidelity level (Alexiades, 1996). Fidelity level shows the percentage of informants claiming the use of a certain plant species for the treatment of a certain ailment. It was calculated as:

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

where N_p is the number of informants that claim the use of plant species to treat particular disease and N is the number of informants that use that plant as a medicine to treat any disease. The plant species with the highest FL value is considered the most preferred species for a particular ailment category.

3. Results and discussion

3.1. Diversity of medicinal plants and indigenous use

Our study documented a total of 48 species of commonly used medicinal plants in the area, which was represented by 33 families and 40 genera. The families with the highest number of species were Asteraceae (5 species), Rutaceae (4 species), Gentianaceae (3 species) and Polygonaceae (3 species). The families Cucurbitaceae, Ranunculaceae, Rubiaceae and Saxifragaceae were represented by 2 species each, while the remaining 25 families constituted single species only. Several previous studies carried out in the highlands of central and western Nepal (eg. Uprety et al., 2010; Rokaya et al., 2010; Shrestha et al., 2014), have documented higher number of medicinal species from Asteraceae, Rutaceae, Gentianaceae, Polygonaceae and Saxifragaceae similar to our findings, which indicates that, members of these families may have high bio-active compounds with significant therapeutic potential. Our study has documented an additional 36 species of medicinal plants not reported by Rai (2003) and 38 species not reported by Gautam (2011), from the districts adjacent to our study area.

The majority of the species were herbs (27 species) followed by shrubs (10 species), trees (4 species), vines (4 species), climbers (1 species), fungi (1 species) and lichen (1 species). Of the documented plants, 40 species were dicots while only a small proportion were monocots (4 species). Gymnosperms and lower plants were represented by 2 species each. Herbs and shrubs constitute an important part of sub-alpine and alpine vegetation in Nepal (Chaudhary, 1998). Since rural people living in the remote terrain of the Himalaya lack direct access to modern medicines, it is highly possible that people living in these regions have explored therapeutic potential of the plants that grow in their surroundings. Higher utilization of herbs and shrubs is, therefore, directly related to their higher availability in the Himalaya. Similar reports have been documented in other studies carried out in the sub-alpine and alpine regions of Nepal (Shrestha and Dhillion, 2003; Kunwar et al., 2006; Rokaya et al., 2010; Shrestha et al., 2014).

The detailed list of medicinal plants including their life forms, parts used and mode of administration is given in Table 1. Healers and local people considered their knowledge to be their own traditional secret and they believed that disclosing it would decrease potency of their medicines. Therefore, as per their request, we have not included the exact dose of individual medicines in

Table 1
Medicinal plants used by local communities of Tinjure-Milke-Jaljale area in Sankhuwasabha district, East Nepal.

Species	Family	Local name	Life form	Parts used	Use value	Local use
Abelmoschus moschatus Medik.	Malvaceae	Ban aalu	Herb	Bark	0.44	A fine paste of bark is applied to cuts and wound.
Aconitum ferox Wall. ex Ser.	Ranunculaceae	Seto bikhma	Herb	Root	0.72	Small portion of dried root is chewed directly (after proper detoxification) or taken with boiled water to treat diarrhea, stomach disorder and high blood pressure. Also used during fever, cough/cold and body ache.
Aconitum laciniatum (Bruhl) Stapf	Ranunculaceae	Kalo bikhma	Herb	Root	0.57	Small portion of dried root is chewed directly (after proper detoxification) or taken with boiled water during diarrhea and food poisoning.
Aralia cachemirica Decne.	Araliaceae	–	Shrub	Root	0.33	A fine paste of root is applied to cuts and wound to stop bleeding. Also used to treat gastritis and stomach disorder.
Araucaria bidwillii Hook.	Araucariaceae	Thingre salla	Tree	Leaf, Bark	0.55	Dried leaf is crushed and then boiled with water to prepare tea. It is consumed to treat cancer and heart diseases. Bark and leaves are chewed directly to treat gastritis and body ache.
Arisaema jacquemontii Blume	Araceae	Baako	Herb	Tuber	0.40	A fine paste of tuber is prepared and consumed daily during gastritis.
Artemisia indica Willd.	Asteraceae	Gandhe jhar	Herb	Leaf	0.75	Fresh leaves are grinded and directly applied to cuts and wound.
Artemisia dubia L. ex B.D.Jacks.	Asteraceae	Titepate	Herb	Leaf	0.40	Leaves are boiled with water and the warm water is used to take bath to cure scabies and other skin diseases. Leaf extract is also used to get rid of intestinal worms.
Astilbe rivularis Buch.-Ham. ex D. Don	Saxifragaceae	Budo okhati	Herb	Root	0.70	Dried root is directly chewed during body pain and stomach disorder. Root powder is mixed with milk, rice or other foods and consumed to cure post-partum complications. Root paste is mixed with rice flour and used during crack and fracture.
Berberis aristata DC.	Berberidaceae	Chutro	Shrub	Root	0.60	Root extract is consumed during final stage of jaundice.
Bergenia ciliata (Haw.) Sternb.	Saxifragaceae	Pakhanbed	Herb	Rhizome	0.58	Dried root is directly chewed during toothache. Root powder is cooked with ghee and flour and consumed during cough, tonsillitis and fever. It is also used to cure post-partum complications and reduce body pain. Root paste is applied on fractured parts as well as cuts and wounds.
Cinnamomum tamala (Buch.-Ham.) T. Nees & Eberm.	Lauraceae	Sinkauli	Tree	Leaf, Bark	0.40	Leaf and bark extract is used to cure intestinal disorders and gastritis.
Coccinia grandis (L.) Voigt	Cucurbitaceae	Golkakri	Vine	Root	0.30	Root extract is consumed during pneumonia, tonsillitis and throat infection. Dried root is directly chewed to relieve joint pain.
Corydalis govaniana Wall.	Papaveraceae	Bhutkeshi	Herb	Whole plant	0.63	Whole plant is soaked in water overnight and the water is taken next morning to relieve body pain.
Dactylorhiza hatagirea (D. Don) Soo	Orchidaceae	Panchaunle	Herb	Tuber	0.55	Tuber is grinded and a fine paste is prepared. It is applied on cuts and wounds. Dried tuber is directly chewed to relieve body pain and provide energy.
Daphne bholua Buch.-Ham. ex D. Don	Thymelaeaceae	Lokta	Shrub	Root	0.75	Root is grinded and mixed with water. It is consumed during stomach disorder.
Euodia fraxinifolia (D. Don) Hook. f.	Rutaceae	Khanakpa	Tree	Seed, Fruit	0.53	Seed paste is mixed with water and consumed during indigestion and stomach disorder. It is also used in fever and headache.
Heracleum nepalense D. Don	Apiaceae	Chingfing	Shrub	Seed, Fruit	0.67	Seed is grinded and used as pickle to treat stomach disorder, indigestion, fever and headache.
Leptodermis lanceolata Wall.	Rubiaceae	Bhuichampa	Shrub	Root	0.50	Grinded root is mixed with rice flour and applied to fractured parts.
Lilium nepalense D. Don	Liliaceae	Ban lasoon	Shrub	Bulb	0.60	Bulb juice is used as a tonic.
Momordica dioica Roxb. ex Willd.	Cucurbitaceae	Ban karela	Climber	Root	0.50	Finely crushed root powder is mixed with water and filtered with muslin cloth. The extract is consumed every morning during jaundice.
Nardostachys jatamansi (D.Don) DC.	Caprifoliaceae	Jatamansi	Herb	Rhizome, Leaf	0.60	Root is grinded and a fine powder is prepared. It is boiled with water and consumed to cure mental disorder. Smoke from burnt rhizome is inhaled during fever and common cold. Root and leaf is used as incense.
Neopicrorhiza scrophulariiflora (Pennell) D.Y. Hong	Plantaginaceae	Kutki	Herb	Root, Whole plant	0.90	Dried root is consumed directly to cure high blood pressure and common cold. Finely crushed root powder is boiled with water and consumed during fever, sinusitis and jaundice. Root paste is applied on wounds.
Ophiocordyceps sinensis (Berk.) G. H. Sung, J. M. Sung, Hywel-Jones and Spatafora	Ophiocordycipitaceae	Yarsagumba	Fungi	Whole fungus	0.38	Whole fungus is consumed with a glass of milk as a tonic. It is believed to provide strength to the body.
Osbeckia stellata Buch.-Ham. ex Ker Gawl.	Melastomataceae	Asare	Herb	Stem	0.60	Stem is used as toothbrush to cure toothache and gum problem.
Paris polyphylla Sm.	Melanthiaceae	Satuwa	Herb	Root	0.96	Finely crushed root powder is boiled with water and filtered with muslin cloth. The extract is consumed to cure gastritis, piles, high blood pressure, heart diseases, cough and fever. Also used as anti-cancer medicine. Root paste is applied in cuts and burnt parts as well as to treat bodyache.
Phytolacca acinosa Roxb.	Phytolaccaceae	Jaringo	Herb	Root	0.50	Root is grinded smoothly and mixed with water. The extract is filtered with muslin cloth and the filtrate is consumed every morning to cure gastritis and stomach

Table 1 (*continued*)

Species	Family	Local name	Life form	Parts used	Use value	Local use
						disorder.
Piper longum L.	Piperaceae	Pipla	Vine	Fruit	0.67	Fruit is chewed directly during cough and cold.
Rheum acuminatum Hook. f. & Thomson	Polygonaceae	Khokim	Herb	Rhizome	0.60	Rhizome is directly consumed or boiled with water to prepare tea, which is used during cough and cold. It is also consumed to cure gastritis, back pain and post-partum disorders. Rhizome paste is applied on wounds.
Rheum australe D. Don	Polygonaceae	Padamchal	Herb	Rhizome	0.40	Rhizome extract is consumed during pneumonia and internal injury. Rhizome paste is applied on the cracked and fractured parts.
Rheum nobile Hook. f. & Thomson	Polygonaceae	Kejoku (Keju)	Herb	Rhizome	0.40	Rhizome is soaked in water overnight and taken in the morning to cure common medical ailments.
Rhodiola himalensis (D. Don) S. H. Fu	Crassulaceae	Maraguru	Herb	Root	0.42	Root extract is used to relieve stress and provide energy to the body.
Rubia manjith Roxb. ex Fleming	Rubiaceae	Majitho	Vine	Root	0.50	Root paste is applied on the affected parts to treat scabies and other skin diseases.
Saussurea gossypiphora D. Don	Asteraceae	Bhutkesh	Herb	Whole plant	0.40	Wooly cotton from the plant is soaked in water and applied on fractured parts and wounds.
Senecio scandens Buch.-Ham. ex D. Don	Asteraceae	–	Herb	Stem	0.38	An extract of finely crushed stem is used during jaundice
Sonchus wightianus DC.	Asteraceae	Mulapate	Herb	Root	0.47	Root is directly taken to cure tonsillitis, gastritis and jaundice.
Swertia angustifolia Buch.-Ham. ex D. Don	Gentianaceae	Bhale chiraito	Herb	Root, Stem	0.32	Root and sometimes stem as well as leaves are boiled with water and consumed during common cold and fever
Swertia chirayita (Roxb. ex Fleming) Karsten	Gentianaceae	Chiraito	Herb	Whole plant	0.98	Root as well as stem and leaves are boiled with water and consumed to treat common cold, cough, fever, body ache, typhoid, high blood pressure, pneumonia and sinusitis. Also used to get rid of roundworms.
Swertia multicaulis D. Don	Gentianaceae	Sarmaguru	Herb	Root	0.38	Root is boiled with water and consumed to treat fever and other internal injuries. It is also used as tonic. Root of this plant is believed to have special healing property.
Taxus wallichiana Zucc.	Taxaceae	Loth salla	Tree	Leaf, Bark	0.54	Bark of tree as well as leaves is boiled with water and taken to cure cancer and heart diseases.
Tinospora sinensis (Lour.) Merr.	Menispermaceae	Gurjogano	Vine	Root	0.60	Root paste is applied on fractured parts. Extract from root is also consumed during gastritis and diarrhea.
Urtica dioica L.	Urticaceae	Sisnoo	Herb	Leaf, Flower	0.40	Leaves and flowers are boiled with water and taken to cure high blood pressure. Leaf paste is also applied on the wounds caused by dog bite.
Usnea orientalis Motyka	Parmeliaceae	Jhyau	Lichen	Whole Lichen	0.67	Whole lichen is grinded and applied on cuts and wounds.
Viscum album L.	Santalaceae	Hadchur	Shrub	Whole plant	0.72	Whole plant is crushed and applied to cracked and fractured parts. It is mixed with rice flour and applied on the affect parts. Paste is applied on cuts and wounds. Whole plant is boiled with water and consumed to get relief from body pain. Also used to treat post-partum disorders.
Zanthoxylum acanthopodium DC.	Rutaceae	Boke timur	Shrub	Fruit	0.63	Fruit is directly chewed to cure high blood pressure. Fruit is boiled with water and is consumed during gastritis, diarrhea and stomachache.
Zanthoxylum armatum DC.	Rutaceae	Timur	Shrub	Fruit	0.44	Fruit is either chewed directly or boiled with water to treat cough/cold, gastritis and stomachache. It is also used to get rid of roundworms.
Zanthoxylum oxyphyllum Edgew.	Rutaceae	Siltimur	Shrub	Fruit	0.40	Fruit is used to cure gastritis and headache. It is either chewed directly or boiled with water.
Zingiber officinale Roscoe	Zingiberaceae	Aduwa	Herb	Rhizome	0.40	Rhizome is directly chewed to cure cough and cold. It is also used during headache.

Table 2
Ailment categories of 37 human ailments.

Ailment categories	Human ailments
Cancer	Cancer
Cardio-vascular disorders	Heart diseases
	High blood pressure
Cough and cold	Common cold
	Cough
Cuts and wounds (incl. burns)	Cuts
	Wounds
	Burns
Dermatological infection	Scabies
	Skin diseases
Gastro-intestinal disorders	Diarrhea
	Food poisoning
	Gastritis
	Indigestion
	Jaundice
	Piles
	Stomach disorder
	Stomachache
	Typhoid
Gynecological disorders	Post-partum disorder
Headache/fever	Fever
	Headache
Neurological disorders	Mental disorder
Respiratory disorders	Pneumonia
	Sinusitis
	Throat infection
	Tonsillitis
Skeleto-muscular disorders	Back pain
	Body pain
	Crack and fracture
	Joint pain
Tonic/stimulant	Stimulant
	Tonic
Tooth and gum problems	Gum problem
	Toothache
Worm infection	Intestinal worm
	Round worm

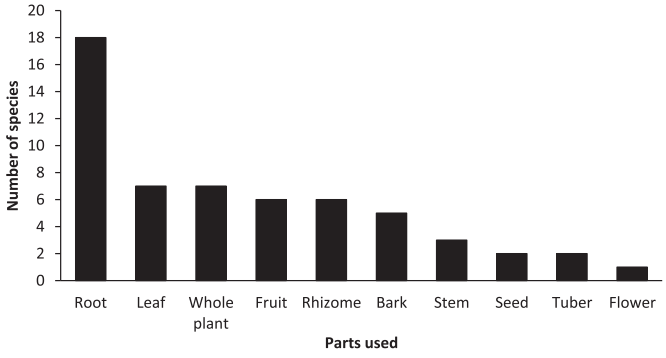

Fig. 2. Proportion of plant parts used to treat 37 human ailments.

this paper. The documented plants were used in the treatment of 37 human ailments (Tables 1,2) in our study area. These ailments were grouped under 14 categories (Table 2). Root was the most utilized part (18 species) followed by leaves and whole plants (7 species each), fruits and rhizomes (6 species each), bark (5 species), stem (3 species), seed and tuber (2 species each) and flower (1 species) (Fig. 2). In particular, roots have been found to contain high amounts of bioactive compounds (Robinson, 1974) which could account for the higher utilization of roots compared to other parts. Ethno-medicinal studies in other regions of Nepal have reported similar utilization patterns of various plant parts (Shrestha and Dhillion, 2003; Rokaya et al., 2010; Uprety et al., 2010; Shrestha et al., 2014).

Our results showed a high degree of similarity with the use reports of medicinal plants from studies based in other regions of the country (Joshi and Edington, 1990; Shrestha and Dhillion, 2003; Bhattarai et al., 2006; Rokaya et al., 2010; Uprety et al., 2010; Luitel et al., 2014; Shrestha et al., 2014). However, some of the uses are reportedly new for Nepal and further biochemical assessment of the compounds isolated from such plants could promote novel drug discovery. We found previously undocumented use of *Abelmoschus moschatus* and *Aralia cachemirica* for wound healing, *Araucaria bidwillii* for treatment of cancer, *Aconitum ferox* for treatment of high blood pressure, *Artemisia dubia* for intestinal worms, *Astilbe rivularis* and *Tinospora sinensis* for fractured bones, *Coccinia grandis* and *Corydalis govaniana* for jointache and body pain and *Osbeckia stellata* for toothache and gum problems. Although medicinal properties of these plants have already been established, their documented uses are different from the present study. Lower ethnobotanical exploration in eastern Nepal compared to central and western part could account for the differences in use reports of these plants.

In order to evaluate if knowledge varies between ethnicity and age groups, we performed further analysis by grouping our key informants into (i) Mongol (Sherpa, Tamang, Gurung, Limbu) and Caucasian (Brahmin, Chhetri) and (ii) younger (≤ 40 years) and older (>40 years) respondents. We performed Kruskal-Wallis H tests in IBM SPSS Statistics v. 21 (IBM, Armonk, NY, USA) to calculate the significance level. We found a statistically significant difference in knowledge level between people of Mongol and Caucasian origin ($\chi^2(1, 59)=5.398$, $p=0.020$). Similarly knowledge of older people (age >40) in terms of medicinal plants utilization were significantly higher than that of the younger generation ($\chi^2(1, 59)=7.710$, $p=0.005$). This lack of knowledge in younger people on plant utilization appears to be a worrying trend worldwide and has been reported in several earlier studies (eg. Monteiro et al., 2006; Poudel et al., 2013).

3.2. Reliability of indigenous use reports

We compared pharmacological actions of medicinal plants documented in this study against published literatures. We found direct pharmacological evidence for the majority of these species. This indicates a high reliability of these medicinal plants in the treatment of various human ailments. For example, extract of *Abelmoschus moschatus*, which has been found to possess antimicrobial properties (Gul et al., 2011) is used by local peoples in wound healing. There are well documented records for the use of *Aconitum ferox* in the treatment of stomach disorder in the Himalaya (eg. Ballabh and Chaurasia, 2007; Rokaya et al., 2010). The gastro-protective effect and cytotoxicity of *Araucaria* resin (Schmeda-Hirschmann et al., 2005) is in accordance with the use of this plant in treating gastritis and cancer. Leaf extract of *Artemisia indica* (Kumar et al., 2007) and aqueous extract of *Bergenia ciliata* (Rashid et al., 2013) has shown antimicrobial and wound healing properties and therefore, the use of these plants in treating cuts and wounds is well justified.

The use of *Berberis aristata* to treat jaundice coincides with the known hepatoprotective effect (Gilani and Janbaz, 1995) of crude extracts of *Berberis aristata* fruits. Methanol extract of *Bergenia ciliata* rhizome has been found to be *anti*tussive and anti-inflammatory (Sinha et al., 2001). The use of *Bergenia ciliata* rhizome to treat cough, tonsillitis and body pain, therefore, coincides with these pharmacological properties. Leaves of *Cinnamomum tamala* possess gastroprotective effects (Eswaran et al., 2010) and it is particularly used to treat intestinal disorders and gastritis in the study area. *Corydalis govaniana,* which is used to reduce body pain, has been proven to have significant analgesic activity (Muhammad et al., 2015). The established aphrodisiac property of *Dactylorhiza*

hatagirea (Thakur and Dixit, 2007) supports the use of this species as an energy booster. *Nardostachys jatamansi* is shown to have *anti*convulsant activity (Arora et al., 1985) and its use in treating mental disorder is in accordance with this known effect. Root paste of *Rubia manjith* has been found to have antiseptic properties (Rajbhandari et al., 1995; Shrestha et al., 2014) and the use of root paste to treat scabies and skin diseases is in accordance to its established property. Similarly, the use of *Osbeckia stellata* in toothache and gum problem is supported by the fact that methanol extract of *Osbeckia stellata* has an anti-inflammatory effect (Yang et al., 2012). Taxol extracted from *Taxus wallichiana* is a well-established anti-cancer drug (Wani et al., 1971) and this plant is particularly used to cure cancer in the region.

Some of the documented plants have lesser known pharmacological potential as systematic and reliable studies on these plants are lacking. This normally applies to plants with new use reports and species not prioritized by the Government of Nepal (see Government of Nepal, 2012 for list of prioritized medicinal species in Nepal). Since there was high consensus among the informants about the use of these plants, their medicinal properties cannot be neglected. It is important to note that ethnobotanical investigations in the past have led to the development of important anti-cancer drugs such as *podophyllotoxin* and *reserpine*, as well as drugs such as *vinblastine* effective in treating hypertension (Idu, 2009). Hence, careful and systematic screening of compounds isolated from these plants could provide a good opportunity for the discovery of new medicines to treat life-threatening human diseases.

3.3. Homogeneity of informant's knowledge

The F_{IC} value ranged between 0.38 and 1 with about 50% of values greater than 0.80 and about 75% of values greater than 0.70, indicating moderate to high consensus among the informants (Table 3). Neurological disorders had the highest value ($F_{IC}=1$), followed by cancer ($F_{IC}=0.93$), headache/fever ($F_{IC}=0.89$), gynecological disorders ($F_{IC}=0.87$), cuts/wounds ($F_{IC}=0.88$) and skeleto-muscular disorders ($F_{IC}=0.81$). The ailments with the lowest consensus were respiratory disorders ($F_{IC}=0.38$) and tonic/stimulant ($F_{IC}=0.40$). High F_{IC} values for a majority of ailments in the present study shows homogeneity of informant's knowledge thereby reinforcing medicinal properties of the documented plants.

Table 3
Informant consensus factor for different ailment categories.

Ailment categories	Number of use reports (N_{ur})	Number of taxa (N_t)	Informant consensus factor (F_{IC})
Cancer	29	3	0.93
Cardio-vascular disorders	27	9	0.69
Cough and cold	33	11	0.69
Cuts and wounds	101	13	0.88
Dermatological infection	6	2	0.80
Gastro-intestinal disorders	99	23	0.78
Gynecological disorders	24	4	0.87
Headache/fever	90	11	0.89
Neurological disorders	2	1	1.00
Respiratory disorders	9	6	0.38
Skeleto-muscular disorders	79	16	0.81
Tonic/stimulant	11	7	0.40
Tooth and gum problems	5	2	0.75
Worm infection	6	3	0.60

A large number of taxa were used for the treatment of gastro-intestinal disorders (23 species), skeleto-muscular disorders (16 species), cuts/wounds (13 species), cough/cold (11 species) and headache/fever (11 species), which indicates that prevalence of these ailments is very high in the study area. The use of substantially higher number of species to treat gastro-intestinal disorders also indicates its higher prevalence in the area, particularly due to poor sanitation. This is a common scenario in almost all the rural communities of Nepal (Rokaya et al., 2010). In order to cope with this issue, local people have, therefore, developed their own methods of treatment by exploring the therapeutic potential of several plant species (Shrestha et al., 2014).

3.4. Use value and fidelity level

Swertia chirayita (Fig. 3A) was the most preferred species in the study area with a high use value (UV=0.98). Ninety percent of people interviewed stated one or multiple uses of *Swertia chirayita*. Higher preference of *Swertia chirayita* could be due to its higher availability in the area as well as its established pharmaceutical potency. In almost all the Himalayan districts of Nepal, including our study area, cultivation and trade of *Swertia chirayita* provides an important livelihood for many rural people. It is also one of the most utilized species for the treatment of fever and other common human ailments in the Sankhuwasabha district, as well as other parts of Nepal (Ghimire et al., 2001; Rokaya et al., 2010; Shrestha et al., 2014). *Swertia chirayita* has, therefore, established itself as an important medicinal herb in the high hills of Nepal.

Paris polyphylla (UV=0.96, Fig. 3B) and *Neopicrorhiza scrophulariiflora* (UV=0.90, Fig. 3C) were the next preferred species in the area, and their use reports were confirmed by 85% and 61% respondents respectively. Like *Swertia chirayita*, these two species are equally popular in the hilly regions of Nepal and their pharmacological actions are well established.

The priority level of two Himalayan species, *Nardostachys jatamansi* (UV=0.60) and *Dactylorhiza hatagirea* (UV=0.55) were significantly lower (only 10–20% of the respondents reported their use). Similar study carried out in central Nepal (Shrestha et al., 2014), however, reported high use values for these species. Differences in community composition could account for this variation, as the study of Shrestha et al. (2014), reported uses of a single ethnic group, whereas in the present study the community composition is more diverse.

We considered the highest FL (%) in each ailment category to choose the most preferred species. We found 29 popular plants for the treatment of 14 ailments (Table 4). *Taxus wallichiana* was the most preferred species for the treatment of cancer (FL=87.5%) followed by *Araucaria bidwillii* (FL=66.67%). *Urtica dioica* (FL=50%) was the species most popular in treating cardio-vascular diseases. Similarly, *Abelmoschus indica* (FL=100%) and *Rubia manjith* (FL=100%) were preferred for treating cuts/wounds and dermatological infection, respectively. Since use reports of gastro-intestinal disorders were high, substantially higher numbers of species were preferred for treating this ailment. Most of the preferred species in the area have established pharmacological potential, which indicates that the medicinal properties of plants documented herein provide valid information on the specific use of these species.

3.5. Harvesting and management of medicinal plants

The majority of medicinal plants are predominantly wild harvested from the forests exempting a few cultivated species. Of the interviewed people, 88% relied on wild harvested plants and the remaining 12% on cultivated species. At present, only 21

Fig. 3. Most preferred species of medicinal plants in TMJ area. (A) *Swertia chirayita* (Roxb. ex Fleming) Karsten (B) *Paris polyphylla* Sm. (C) *Neopicrorhiza scrophulariiflora* (Pennell) D.Y. Hong.

Table 4
Most frequently used plants in each ailment category based on highest fidelity level.

Ailment categories	Species	Fidelity level (%)
Cancer	*Taxus wallichiana*	87.50
	Araucaria bidwillii	66.67
Cardio-vascular disorders	*Urtica dioica*	50.00
Cough and cold	*Piper longum*	100.00
	Zingiber officinale	50.00
Cuts and wounds	*Abelmoschus moschatus*	100.00
	Artemisia indica	100.00
	Usnea orientalis	100.00
	Paris polyphylla	77.42
	Dactylorhiza hatagirea	75.00
Dermatological infection	*Rubia manjith*	100.00
Gastro-intestinal disorders	*Euodia fraxinifolia*	80.00
	Sonchus wightianus	80.00
	Zanthoxylum armatum	76.92
	Zanthoxylum oxyphyllum	70.00
	Cinnamomum tamala	100.00
Gynecological disorders	*Astilbe rivularis*	54.55
Headache/fever	*Swertia angustifolia*	66.67
	Swertia chirayita	58.24
Neurological disorders	*Nardostachys jatamansi*	33.33
Respiratory disorders	*Coccinia grandis*	66.67
	Rheum australe	33.33
Skeleto-muscular disorders	*Corydalis govaniana*	100.00
	Leptodermis lanceolata	100.00
	Viscum album	89.66
Tonic/stimulant	*Lilium nepalense*	100.00
	Ophiocordyceps sinensis	100.00
Tooth and gum problems	*Osbeckia stellata*	100.00
Worm infection	*Artemisia dubia*	66.67

households are involved in cultivation of medicinal plants. Four major species: *Swertia chirayita, Paris polyphylla, Taxus wallichiana* and *Astilbe rivularis* are currently being cultivated. Since cultivation is limited to a few species, people largely depend upon wild harvested products to meet their local demand. This has put high pressure on the resources, which in turn has fostered unsustainable harvesting in the area.

Ninety three percent of the respondents stated that they uproot whole plants without leaving any parts for regeneration on the ground. Since root is the most utilized part for majority of medicinal plants (see Fig. 2), uprooting whole plants is a common practice in the area, and this has seriously degraded the resources. Species such as *Nardostachys jatamansi* are highly vulnerable to harvesting (Ghimire et al., 2001), as are other Himalayan species (eg. *Dactylorhiza hatagirea* and *Neopicrorhiza scrophulariiflora*). Therefore, the species whose underground parts are utilized need to be harvested using careful and systematic harvesting techniques (Shrestha and Shrestha, 2012).

Although people admitted that resources are in dwindling supply, they seemed helpless in protecting them, chiefly due to uncontrolled poaching activities. Since the area does not lie within the jurisdiction of the Department of National Parks and Wildlife Conservation, resources are rampantly collected. There are no check points to monitor these activities and hence the valuable resources are depleting at a rapid rate. Therefore, the first step towards management of resources in the TMJ area would be support from the Government and/or concerned authorities to check illegal collection of wild resources. The second step could be promotion of cultivation practices, since cultivation of locally available medicinal plants provides the most cost-effective and viable solution to protect the depleting resources as well as economically support the local people who depend upon it (Sharma et al., 2005). It is, therefore, necessary to reinforce existing cultivation practices by offering required expertize to local farmers and by creating a conducive environment in which the cultivated products are profitably marketed with high economic return to the local people (Shrestha et al., 2014). At the same time, the authors suggest other income generation activities should be introduced in the area in order to reduce sole dependency on wild medicinal resources.

4. Conclusion

The present study has identified medicinal properties of 48 species of wild plants, which is widely used in local therapeutics in the remote terrain of eastern Nepal. The plants belonged to 33 families and 40 genera and were used in the treatment of 37 human ailments. A large number of species were used to treat gastro-intestinal disorders which indicate its higher prevalence in the area, particularly due to poor sanitation. In order to cope with this issue, local people have explored the medicinal properties of several species that grow in their surroundings. The majority of medicinal plants documented in the present study chiefly belong to few flowering plants families such as Asteraceae, Rutaceae, Gentianaceae, Polygonaceae and Saxifragaceae. Since the medicinal properties of the species in these families have also been

consistently recognized in the past studies, this might indicate that these families possess therapeutically significant bio-active compounds. Further studies are, however, needed to verify if alternative species in these families have similar medicinal properties. Our study additionally reported undocumented use of 10 medicinal plants (see 3.1 Diversity of medicinal plants and indigenous use) whose medicinal properties were known but not in the manner they are being utilized in the present study. A high degree of consensus on the use of these plants suggests that the species likely have high therapeutic potential. Furthermore, medicinal properties of a majority of documented species are in agreement with established pharmacological action, which potentially indicates high reliability of medicinal plants in the treatment of various ailments. Careful and systematic screening of compounds isolated from these plants could provide good opportunity for the discovery of new medicines to treat life-threatening human diseases. Particularly species with new use reports have lesser known pharmacological potential due to lack of systematic and reliable studies. Since there was high consensus among the informants about the use of these plants, their medicinal properties cannot be neglected. Future researches should therefore, be directed towards isolating bio-active compounds from these valuable plants and systematically assessing their pharmacological properties.

The majorities of the species documented in the present study have high use value and are of high indigenous priority. Since these species are unsustainably harvested, they are exposed to a high threat risk. Plants whose roots are utilized as medicines are potentially vulnerable because most of them are either harvested before the flowering season or the whole plant is uprooted without leaving any parts for regeneration. The need to harvest unsustainably is accentuated further due to higher commercial demand of many species. This practice will not only deplete the existing resources, but also affect traditional utilization of many medicinal plants. With decreasing availability of medicinal plants, people will be less likely to utilize them and over time, their traditional knowledge may be completely lost. Ethnobotanical documentation such as this study will then only serve as a historical record without pragmatic benefits. Therefore, it is equally important to sustainably manage the existing resources. Cultivation of medicinal plants could be one viable option to counterbalance the pressure on depleting resources. The high priority species such as *Swertia chirayita* and *Paris polyphylla* have established pharmacological actions and are widely utilized by indigenous people to treat a number of human ailments. The local demand is, however, solely fulfilled from the wild resources. Although these species are cultivated in few villages at present, cultivation is still in the preliminary stage and people lack technical expertise to grow these plants. Therefore, we address the need of reinforcing existing cultivation practice by providing proper technical assistance to local people. We also address the need of establishing monitoring points to check illegal collection and trade of medicinal plants. It is important to note that the knowledge on utilization of medicinal plants reported here belongs to the indigenous people of the study area and therefore, the benefits generated from this knowledge should be equally shared with them. Since we have not mentioned exact dose and precise method of drug administration, we strongly advise not to practice it independently as some of the medicinal plants reported here are among the most poisonous plants in the world.

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