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Integrating Ecological and Ethnobotanical Knowledge to Promote Collaborative Conservation Planning in the Nepal Himalaya

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The Manaslu Conservation Area in north-central Nepal is considered a biodiversity hotspot, but very little is known about the ecology of its forests and its residents' ethnobotanical practices. This study integrated data from ecological sample plots in 19 forest patches and an ethnobotanical inventory conducted with village residents to explore spatial patterns of diversity in woody plant species and their local uses. The study identified a total of 155 woody plant species in 103 genera and 54 plant families. Local residents named 96% (149) of these species and cited 404 uses for them. The uses involving the greatest number of species were fuel (104) and fodder (54). Seven forest community types were identified: 2, blue pine and rhododendron, primarily below 2200 m, and 5 communities (mixed laurel, oak–laurel, mixed maple, oak–ash and kharsu oak) mostly above 2200 m. Among the forest community types, the oak–laurel forest, at 1–3 km from the study villages, had the highest number of species, species used by humans, and different uses. These research findings provide a first assessment of ecological diversity and ethnobotanical resources for the region and highlight concerns for forest resources and opportunities for collaborative conservation planning.

Keywords: *Ecology; ethnobotany; collaborative conservation; knowledge integration; Nepal; Himalaya.*

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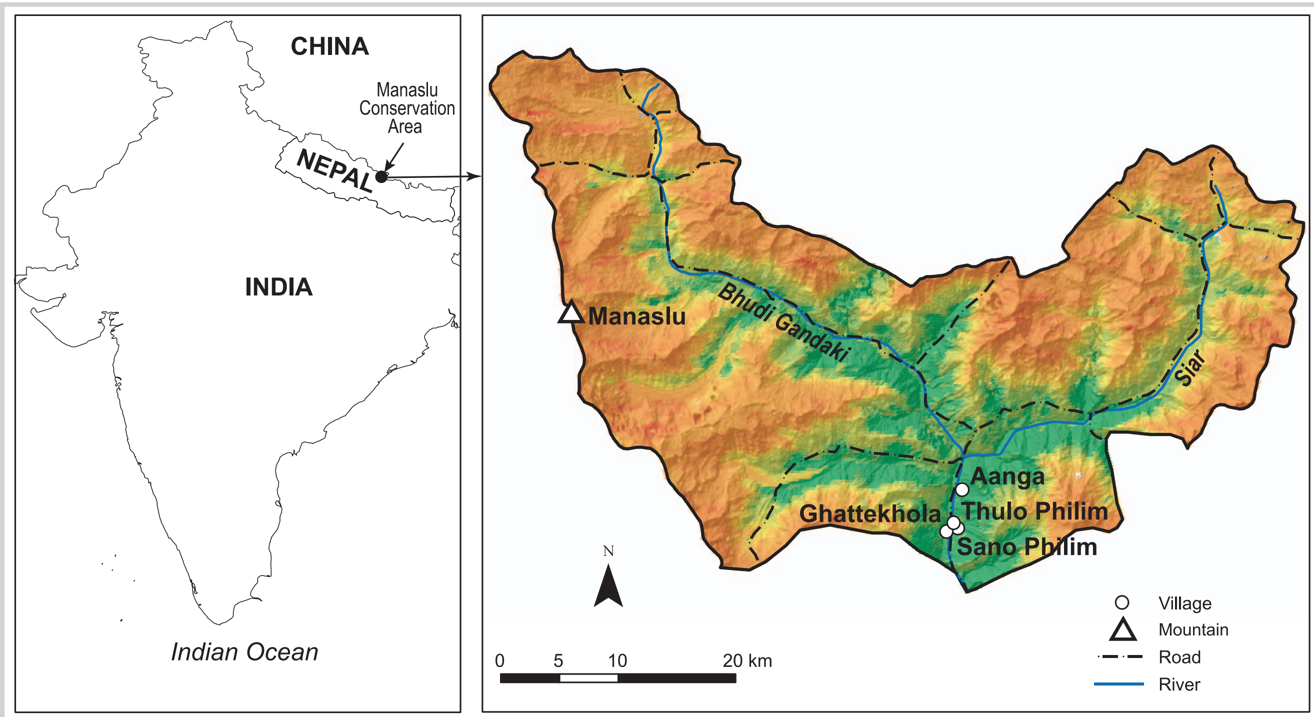
Introduction

The Himalaya Mountains in Nepal are globally recognized as an important biodiversity hotspot (Myers et al 2000) and include 4 of the World Wildlife Fund's Global 200 ecoregions (Olson and Dinerstein 2002). Exceptionally high biodiversity, especially for plants, is explained by dynamic geologic uplift of the Himalaya at an average of 3–5 mm per year (Watson et al 2011); a biogeographic mix of Indo-Malayan, Indo-Chinese, Sino-Himalayan, East Asian, and Euro-Mediterranean flora; and biophysical complexity in relation to extreme vertical relief along the north–south axis that supports a range of diverse habitats (Mittermeier et al 2004).

Ecological studies conducted in the Himalaya focus on plant diversity patterns primarily explained by the elevation gradient (eg Vetaas and Grytness 2002; Bhattarai et al 2014). Such explanations, however, would also benefit from better understanding of human livelihoods in relation to vegetation patterns. Incorporation of a human dimension into diversity pattern studies in mountain research is critical, because people living in a montane environment depend on its diverse vegetation types for their livelihoods (Funnel and Parish 2001) and may have specialized knowledge that can contribute directly to research on mountain ecosystems (UNCED 1992). Plant ecological research should incorporate local ethnobotanical knowledge as it further validates diversity patterns and promotes participation by local people as collaborators in the assessment and conservation management of biodiversity for the benefit of all stakeholders (cf. Becker and Ghimire 2003; Medley and Kalibo 2007).

This research focused on forest plant resources in the Manaslu Conservation Area (MCA) in north-central Nepal (Figure 1), part of the biologically rich eastern Himalaya. Biodiversity data for the MCA are sparse because of its remote location, its relatively short history as a protected area (established in 1998), and a decade-long "people's war" (1996–2007), during which it was under control of Maoist guerrillas. Unlike the better-known neighboring Annapurna Conservation Area (eg Christensen and Heilmann-Clausen 2009), few floristic and ethnobotanical studies have been reported for the MCA (eg Olsen 1998 on medicinal and aromatic plants; Gurung and Pyakurel 2006 on non-timber forest products). Conservation concerns

FIGURE 1 Regional map of the MCA and the location of the study villages. (Data sources: ICIMOD 2009; ESRI 2012; MODIS 2012; map by Sushma Shrestha)



for the MCA heightened after 2007 because of rapid infrastructure development in order to accommodate the influx of tourists searching for a more remote wilderness destination. For example, the number of tourists visiting the MCA was reported to increase from 1827 in 2009 to 5918 in 2014 (National Trust for Nature Conservation [NTNC] 2015).

The purpose of this study was to integrate ecological and ethnobotanical analyses of woody plant diversity in the MCA in order to understand how locally recognized (ethnobotanical) plant resources are distributed in relation to those species' (ecological) composition and structure. The study focused on woody flora because they dominate forest vegetation, correlate with differences among forest community types, and provide an ecologically important measure of extraction and utilization practices (Tabuti et al 2009). Employing mixed methods in a collaborative-learning approach, we explored forest diversity patterns, the cultural significance of plant resources, and ways that shared knowledge might contribute to engaged participation and joint decision-making for biodiversity conservation (Berkes et al 2000; Fabricius et al 2006).

Study area

The MCA landscape is marked by extreme topography that includes massive rock cliffs interrupted by deep gorges carved by the Bhudi Gandaki River and its tributaries (Figure 1). Remoteness and lack of infrastructure make the MCA one of the least explored protected areas in Nepal (Gaire et al 2014). It has an area of 1666 km^2, and elevations range from 600 to 8163 m. Its highest point is the summit of Mt Manaslu, the world's eighth highest mountain. We conducted field research in 4 Gurung settlements located near the southern park boundary: Ghattekhola, Sano Philim, Thulo Philim, and Aanga.

The Gurung are of Tibeto-Burman origin and follow both Hindu and Buddhist religious traditions. Their settlements represent the highest population density within the MCA, and their location near the southern park boundary makes them most likely to experience the greatest impact from externally driven development projects. With only 2% of their land cultivable, they are agropastoralists, farm at multiple locations above and below their villages, and hold rights to land in the grasslands above the montane forests, where they take their cattle in the summer. Each village has access to and control over the forested areas that fall within the village boundary. Forests are highly fragmented; one village might include several forest patches surrounded by agricultural fields, rocky cliffs, and grassland. These villagers are also beginning to engage in trekking tourism and the sale of medicinal plants.

The MCA's climate is monsoonal, with a wet season from June to September and a dry season from October to May. The nearest weather station, at Gorkha, situated

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about 50 miles south of the MCA, recorded a mean annual rainfall amount of 1252 mm from 1980 to 2009 (Mainali et al 2015) and temperatures ranging from 2.4 to 33.4°C in 2001–2008 (Thapa et al 2016). Five ecological zones have been identified in the MCA (Shrestha 2008)—subtropical (1000–2000 m), temperate (2000–3000 m), subalpine (3000–4000 m), alpine (4000–5000 m), and a nival zone above 5000 m. Within these zones are 19 forest types with about 2000 plant species (Rana 2001). Our study, conducted primarily in the temperate zone, included pine and mixed oak forest types.

Unlike the national parks managed directly by Nepal's Department of National Parks and Wildlife Conservation, the MCA is managed by the NTNC, a not-for-profit organization that works with local communities on conservation management and ecotourism development (NTNC 2015). In the MCA, the NTNC works with a conservation area management committee and women's groups, which are composed of local community representatives.

Data and methods

The research was undertaken during 4 field seasons beginning June 2009 and ending January 2013. Permission to work in the MCA was obtained through NTNC and the local residents; the study protocol was approved by the Miami University Institutional Review Board for Human Subjects Research and met the Collaborative Institutional Training Initiative standards for international research. Plant voucher specimens were deposited at the Tribhuvan University of Nepal and Miami University herbariums. Tribhuvan University obtained permission for export of the plant material from Nepal, and a phytosanitary certificate was provided by the National Plant Quarantine Office of Nepal.

Ecological patterns of diversity

Working with local field assistants and village residents, mixed methods were employed to collect and compile data on the ecological composition and structure of 19 forest patches that the assistants and residents selected as important resource areas. Woody plant diversity attributes were recorded for 114 (20 × 10-m) plots in the 19 forest patches: 24 plots in 1 patch at Thulo Philim village, 38 plots in 11 patches at Aanga, 19 plots in 4 patches at Ghattekhola, and 33 plots in 3 patches at Sano Philim. For each plot, trees with diameters at breast height (Dbh) >10 cm as well as all understory small trees, shrubs, and lianas at >1 m height and <10 cm Dbh were measured. Plant vouchers were confirmed using *Concise Flowers of the Himalaya* (Polunin and Stainton 1987), *Flora of China* (Wu et al 1994–2008), *Flora of Bhutan* (Long and Grierson 1983–2002), and *Flora of Nepal* (Watson et al 2011).

The relative importances (calculated as [relative density + relative basal area]/2] of canopy trees >10 cm Dbh were used to classify forest community types. One plot was dropped from the analyses because it lacked trees of this size. Working in PC-ORD (version 6.11; McCune and Mefford 1999), we conducted cluster analysis, using Sorensen (Bray-Curtis) as the distance measure and flexible beta (–0.25) as the linkage method to hierarchically group the plots based on their similarities in species relative importances. Indicator species analysis was then used to choose the optimum number of forest community types based on the peak number of significant indicator species values and the smallest average probability among groups (McCune and Grace 2002). Statistical differences among the chosen groups were tested using multiresponse permutation procedures that provided *t*-statistics and probability values. The derived forest community types were characterized by compositional (species richness, indicator species, species relative importances) and structural (density and basal areas) attributes. All forest plots were mapped by their community type on a Moderate Resolution Imaging Spectroradiometer (MODIS 2012) image in order to examine their distribution patterns in relation to the study villages. Geographic information system layers showing the MCA boundary, major roads, and rivers were obtained from the International Centre for Integrated Mountain Development (ICIMOD 2009).

Ethnobotanical patterns of diversity

Based on peer recommendation (eg Davis and Wagner 2003) from NTNC, 32 male and 36 female respondents between 16 and 70 years old were selected to obtain ethnobotanical data. All participants lived in the study villages and were members of the conservation area management committee or women's groups. Data were collected in 3 steps:

1. The number of uses and categories of uses for plants were documented via free-listing exercises, where focus groups, averaging 4 men and 5 women ($n = 44$) were asked to spontaneously list the names and uses of all the plants they knew. Following Prance et al (1987) and Tardio and Pardo-de-Santayana (2008), plant uses were grouped into 8 use categories: fuel, fodder, food, construction, technology (referring to plants used in making tools, utensils, and furniture and in processes such as production of glues and dyes), health remedies, symbolic, and other uses. Participants were then prompted to list more plants by asking, for each use category, if they knew of any other plants used for that purpose. Plant species mentioned by only 1 focus group were excluded.
2. Interviews were conducted with key informants ($n = 24$) on the vernacular names and uses of the plants at each forest sampling plot.

TABLE 1 Ecological and ethnobotanical diversity of woody plants in the study area.

Ecological diversity		
Measure	Number of taxa	
Species	155	
Genera	103	
Families	54	
Woody plant species >10 cm Dbh	103	
Woody plant species >1 m in height and <10 cm Dbh	53	
Ethnobotanical diversity		
Use	Number of uses	Number of species
Fuel—firewood, charcoal	107	104
Fodder—leaves, fruit	56	54
Food—fruits eaten fresh or as paste; leaves used in preparing tea; seeds, flowers and nectar eaten	51	48
Construction—poles, posts, beams, planks, fencing	48	25
Technology—tools, utensils, furniture, glues, dyes	78	41
Health remedies—leaves, roots, bark, flowers, fruits (boiled, crushed, or pounded) for treating humans and livestock	28	22
Symbolic uses—leaves, flowers, fruits, stems used in rites of passage, religious events, and healing ceremonies	27	22
Other uses—bedding for animals, fertilizer, adornment	9	9
Total woody plant species used by village residents[b]	NA[a]	149
Total uses for woody plant species	404	NA[a]

[a] NA, not applicable.
[b] Many species have more than one use.

3. Participant observations at homes and farms identified and further validated plant names and uses.

We compared the ethnobotanical value of the forest community types by determining the number of woody plant species that were used and the highest number of different uses for each species.

Results

The ecological analyses confirmed a total of 155 woody plant species in 103 genera and 54 plant families, mostly representative of temperate flora (Table 1). Rosaceae (16 species in 7 genera), Ericaceae (8 species, 4 genera), and Lauraceae (7 species, 6 genera) were the most diverse families. The Pinaceae, Aceraceae, Fabaceae, and Fagaceae families had 6 species each, whereas 16 families were represented by only 1 species. About 42% of the plants were trees (65 species in 47 genera and 28 families), 25% were small trees (38 species in 29 genera and 24 families), 28% were shrubs (45 species in 30 genera and 20 families), and 5% were vines (7 species in 7 genera and 6 families). Of the recorded tree species, 19 were measured in only 1 plot, and only 17 species occurred in 11 or more plots.

Study participants named 96% (149 species in 100 genera and 52 families) of these species. They described uses for 144 of these species and a total of 404 uses, some in each of the 8 use categories (Table 1). Only 5 plant species named and identified by participants had no described uses. The cultural significance of the plant species was assessed in terms of their total number of uses and how well those uses were distributed across the 8 use categories. There were more plant uses than species (in other words, at least some species had more than one use) in all use categories except other.

The fuel category had the highest number of species (104) and uses (107). Residents described how different fuelwoods were selected based on the weight or density of the wood, how quickly it burned (slow burning was preferred), and how efficiently it burned (if it sparked or produced smoke). Oak species such as *Quercus*

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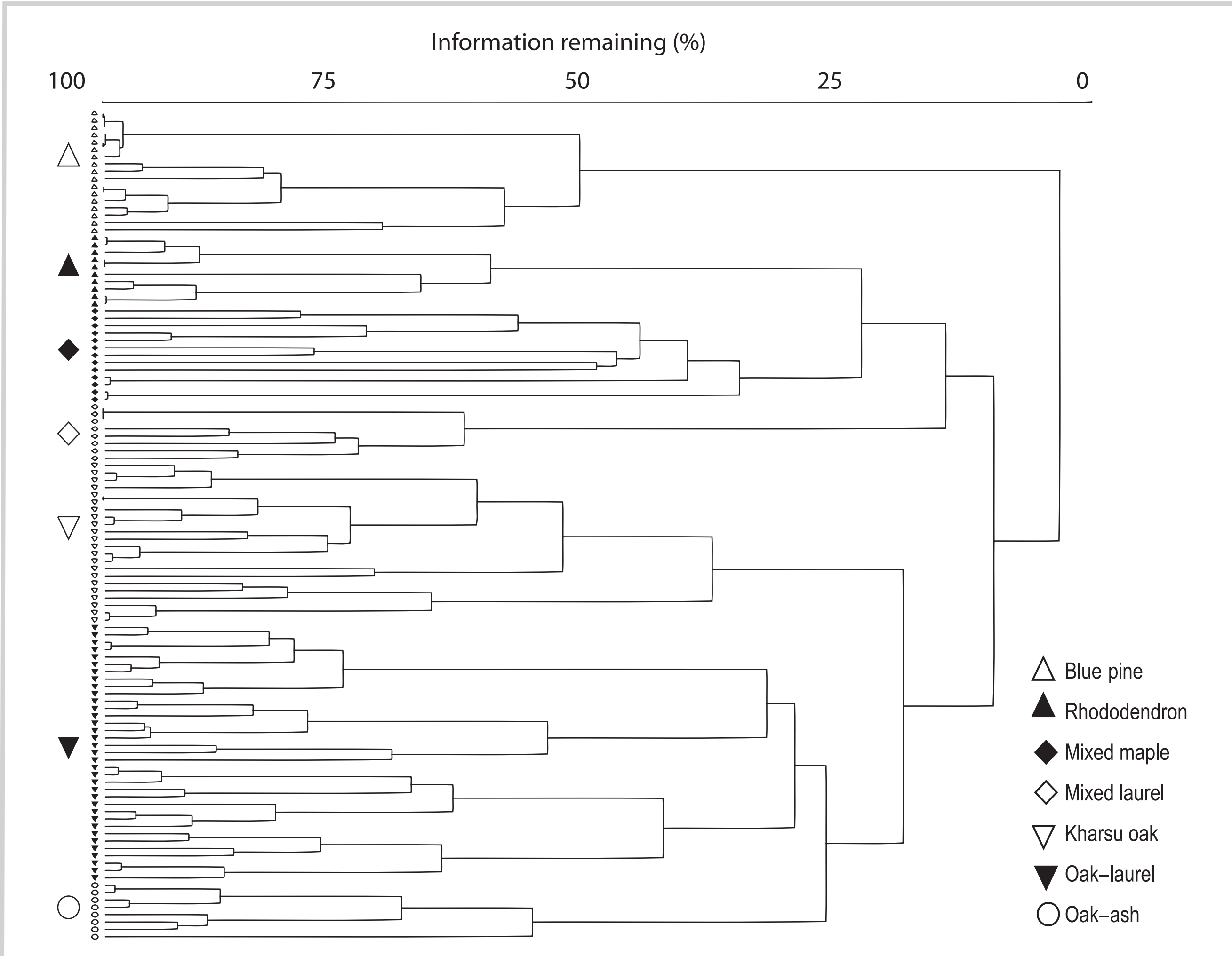
FIGURE 2 Dendrogram showing 7 forest community types.



semecarpifolia and *Cyclobalanopsis* spp were considered by most participants to be the best fuelwood, along with *Rhododendron arboreum*, but they only occurred in forests situated above the villages. In contrast, the tree *Alnus nepalensis* and shrubs like *Berberis chitria* and *Viburnum mullaha* were not preferred but were commonly used because they were easily collected near residents' homes.

The cluster analysis grouped sample plots into 7 groups in the form of a dendrogram or tree diagram (Figure 2). The percentage chaining (frequency with which the individual sample plots were added to the larger groups) of the dendrogram was 2% and was cut with 25% of the information remaining. The indicator species analysis identified 57 significant indicator species representative of each of the 7 groups or community types with the lowest average probability (0.262). Multiresponse permutation procedures confirmed significant differences among these groups ($t = -38.078$, probability= 0.00; McCune and Grace 2002). The 7 forest community types identified in the study area were as follows: blue pine, rhododendron, mixed laurel, oak–laurel, mixed maple, oak–ash and kharsu oak.

The forest types differed by elevation, with evergreen blue pine forest dominated by *Pinus wallichiana* and *R. arboreum*, sometimes with *Pinus roxburghii* (chir pine), mostly below 2200 m, and temperate *Q. semecarpifolia* (kharsu oak), mixed maple, oak–laurel, oak–ash, and mixed laurel forest, mostly above 2200 m (Table 2). Blue pine forests occurred near abandoned fields and grazing areas closest to the settlements. Forest composition and structure changed with elevation from lower dense rhododendron forest into mixed temperate forests. The mixed temperate forests, however distinctive in their indicator species and species importances (Table 2), overlapped across the landscape and sometimes were found in the same forest patch (Figure 3). Kharsu oak forest had the greatest mean basal area (86 m^2/ha), and oak–laurel had the highest mean species richness (44 species). Rhododendron and the blue pine forests shared about 45% of their total plant species, whereas 93% of the

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TABLE 2 Characteristics of the forest community types.[a)]

Forest community type (number of plots)	Elevation mean (m)	Elevation range (m)	Species richness	Density (number/ha)	Basal area (m^2/ha)
Blue pine (17)	2198	1536–2420	25	553	31.11
Rhododendron (10)	2201	2020–2350	20	905	36.95
Mixed laurel (8)	2282	2101–2642	19	713	64.76
Oak–laurel (35)	2432	2175–2720	44	783	60.26
Mixed maple (13)	2439	1960–2854	26	681	32.49
Oak–ash (8)	2457	2346–2560	17	775	76.64
Kharsu oak	2580	2313–2904	29	709	86.35

TABLE 2 Extended.

Forest community type (number of plots)	Indicator species (ISA prob.)	5 most important species (IV%)
Blue pine (17)	*Pinus wallichiana* (<0.001) *Cornus capitata* (0.001)	*P. wallichiana* (51.1) *C. capitata* (13.9) *Carpinus viminea* (4.5) *Lyonia ovalifolia* (3.5) *Alnus nepalensis* (3.3)
Rhododendron (10)	*Rhododendron arboreum* (<0.001) *L. ovalifolia* (<0.001) *Myrica esculenta* (0.001)	*R. arboreum* (43.9) *L. ovalifolia* (15.6) *P. wallichiana* (12.2) *Pinus roxburghii* (8.9) *M. esculenta* (2.3)
Mixed laurel (8)	*Neolitsea pallens* (<0.001) *Viburnum erubescens* (0.001) *Elaeagnus caudata* (0.027)	*N. pallens* (65.3) *Ilex dipyrena* (8.8) *V. erubescens* (3.4) *Sorbus cuspidata* (3.1) *Meliosma simplicifolia* (2.9)
Oak–laurel (35)	*Machilus duthiei* (<0.001) *Cyclobalanopsis glauca* (0.004) *Cyclobalanopsis oxyodon* (0.006) *Betula alnoides* (0.043)	*M. duthiei* (24.0) *C. glauca* (14.1) *C. oxyodon* (11.3) *B. alnoides* (10.4) *N. pallens* (6.3)
Mixed maple (13)	*Acer pectinatum* (0.001) *Toona sinensis* (0.032)	*L. ovalifolia* (14.5) *P. roxburghii* (11.5) *Tsuga dumosa* (9.1) *A. nepalensis* (8.4) *T. sinensis* (8.1)
Oak–ash (8)	*Cyclobalanopsis gambleana* (<0.001) *Fraxinus chinensis* (0.011) *Fraxinus floribunda* (0.043)	*C. gambleana* (44.6) *I. dipyrena* (15.5) *M. duthiei* (10.3) *B. alnoides* (4.7) *F. chinensis* (4.4)
Kharsu oak	*Quercus semecarpifolia* (<0.001) *Populus ciliata* (0.009) *Pieris formosa* (0.034)	*Q. semecarpifolia* (35.1) *I. dipyrena* (8.4) *P. ciliata* (8.0) *M. duthiei* (5.4) *Lindera pulcherrima* (5.3)

[a)] ISA prob., indicator species analysis probability; IV, species importance value.

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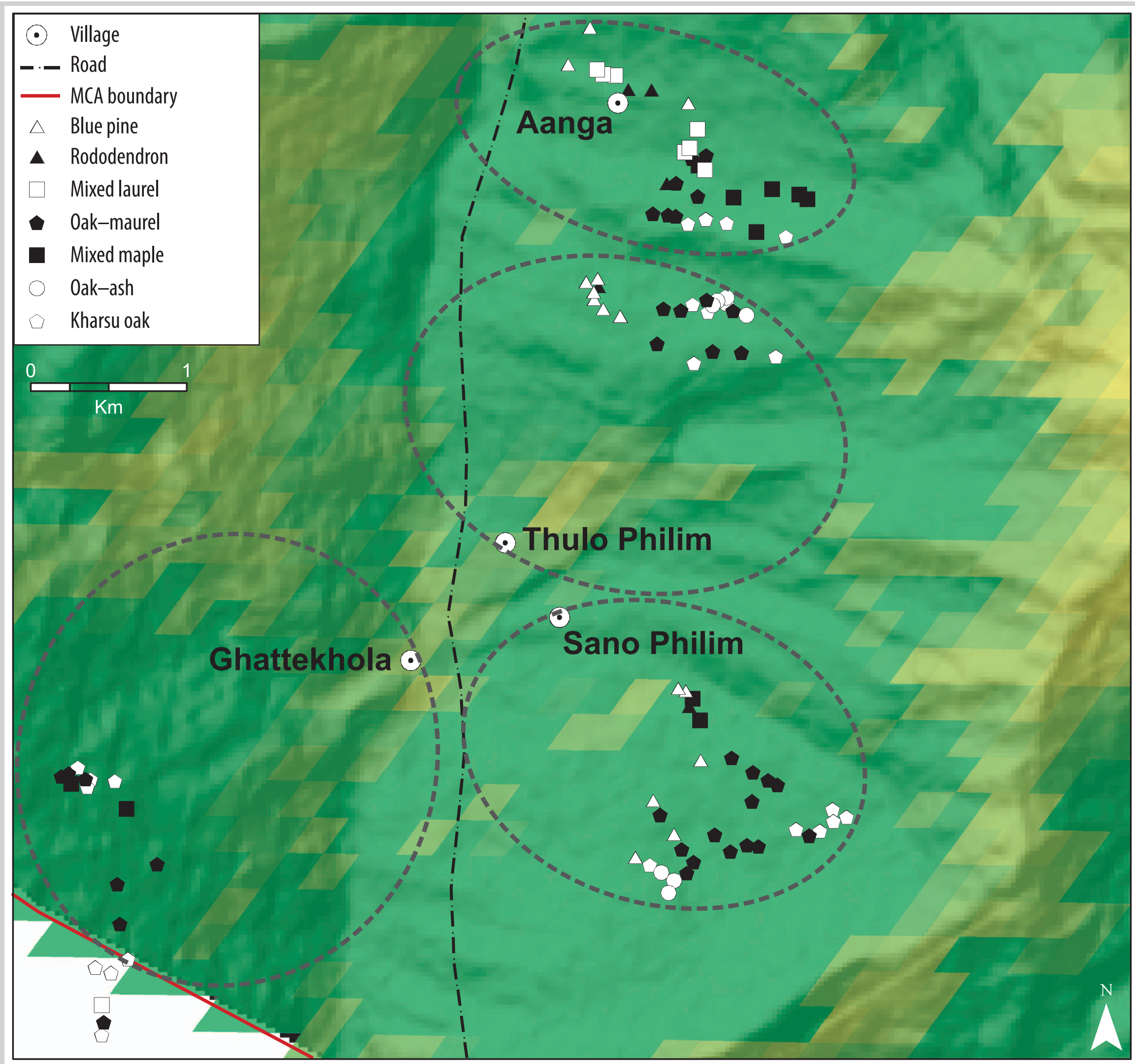
FIGURE 3 Distribution of forest community types. (Data sources: ICIMOD 2009; MODIS 2012)



species present in kharsu oak forests also occurred in oak–laurel forests. Kharsu oak and oak–laurel forests frequently occurred within the same forest patch. For the forest patches selected by study participants in their respective study villages, we identified at least 3 forest community types in each village. The blue pine forest was uniquely absent from Ghattekhola village, whereas all 7 forest community types were represented in the Aanga village patches; 3 forest community types in Ghattekhola village were mapped in patches located beyond the boundaries of the MCA.

The oak–laurel forest had the highest number of species with uses and the highest number of uses across all use categories (Figure 4). Among the 44 species in this forest community type, 39 were used for fuel and 22 had technological uses. The high number of uses for oak–laurel forest could be partially explained by its wide distribution and accessibility from the study villages (Figure 3), but also supports the close relationship between species (ecological) and ethnobotanical diversity in mixed temperate forests for the Gurung at the MCA. Mixed maple forest showed the highest occurrence of species of symbolic importance (Figure 4). The leaves of *Tsuga dumosa* and *P. roxburghii* in this forest community type (Table 2) are used as incense during ceremonies related to birth and death. Few woody plants were used for health remedies; this was true across all forest community types.

Discussion and conclusion

Diversity research in the Himalaya is challenged by a broad elevational gradient of 3000 m for the mountains and a geographic extent of over 3000 km (Zobel and Singh 1997). The purpose of this study was to effectively integrate an

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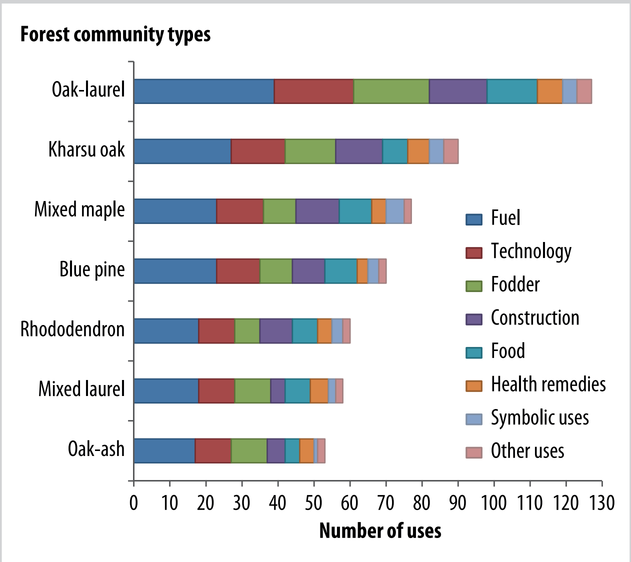
FIGURE 4 Uses for woody plants in the 7 forest community types.



analysis of floristic/ecological patterns of woody plant diversity with a survey of ethnobotanical resources for a single field location, an understudied region in the MCA in the Nepal Himalaya. Gurung residents acknowledge their access to and conservation of forest resources in collaboration with Nepal's NTNC as members of conservation area management committees and women's groups. Our study was designed to integrate ecological and ethnobotanical perspectives on the diversity of woody plant resources as a way to better engage local populations in collaborative planning for biodiversity conservation.

Ecological and ethnobotanical patterns of diversity

Following a participatory approach in applied ethnobotany (Cunningham 2001), we asked participants to guide the research framework by selecting forest patches that were accessible and most utilized by the residents of the 4 study villages. These forests occur as patches in a mosaic of grasslands, shrublands, and agricultural fields with elevations ranging from 1500 to 2800 m. Accordingly, the sample plots measured the composition and structure of woody plants in heavily utilized forest from midmontane pine to upper-montane broadleaved oak forests (Mainali et al 2015).

Floristically, the study reports high species richness in Rosaceae, Ericaceae, and Lauraceae that are representative of temperate forests in east and central Nepal Himalaya (Negi 2000; Stainton 1972). Less frequent species occurrences may be explained by the transitional setting of the forest plots between lower-elevation subtropical and high-elevation subalpine zones (Stainton 1972). The forests of the southern boundary of the MCA show distinct ecological differences in relation to elevation in this montane setting (Lomolino 2001) and are representative of the high diversity documented for temperate oak forests in Himalaya (Zobel and Singh 1997). They are low in endemic species, which are most reported for subalpine forests above the defined study area (Vetaas and Grytness 2002).

The 7 forest community types relate to diversity patterns in temperate forests classified by Stainton (1972), highlighting species importances for *P. wallichiana* (blue pine), *R. arboreum* (rhododendron), *Q. semecarpifolia* (kharsu oak), *Ilex dipyrena* (Himalayan holly), *Machilus duthiei* (Duthie's bay tree laurel), *Neolitsea pallens* (laurel), *Lyonia ovalifolia* (fetterbush), and *Cyclobalanopsis gambleana* (ring-cupped oak). Dominant species occurrences correlate with elevation (Zhang et al 2013), and indicator species such as *Cornus capitata* (Himalayan dogwood), *Myrica esculenta* (bayberry), *Pieris formosa* (Himalayan fetterbush), *Betula alnoides* (Indian birch), *Toona sinensis* (Chinese mahogany), and *Fraxinus floribunda* (Himalayan manna ash) support heterogeneity among temperate forests found in the eastern and central midlands of Nepal (Stainton 1972; Negi 2000). These diversity patterns, however, can only be partly explained by biophysical changes with elevation (Singh and Singh 1987). Where these community types occur in the landscape and where their species overlap are at least partially explained by human influence across the narrow elevational gradient as they are directly managed by the local people (cf. Shrestha et al 2010). As in other montane settings (Bravo-Nogues et al 2008; Guo et al 2013), the potential effect of human activities on diversity patterns can be significant when forests are accessible and used as collection sites for fuelwood, medicine, construction materials, and other material resources—for example, kharsu oak forest transitions toward mixed conifer after fire, grazing, or heavy extraction (Shrestha 2003). Similarly, *P. wallichiana* is considered a secondary species, colonizing mixed broadleaf forests after shifting cultivation and excessive firewood extraction (TISC 2002).

Study participants reported uses for >90% of the plants recorded in the study plots, and most of these plants had multiple uses. Our findings show a direct relationship between ecological patterns of woody plant richness and those plants' ethnobotanical usefulness. The Gurung demonstrate a breadth of forest knowledge and a reliance on extractive products for their livelihoods, which are common among people living in isolated montane environments (cf. Salick et al 1999 for the Dusun of Mt Kinabalu; Salick et al 2004 for the Tibetans of Menri).

Most plant species have multiple uses, which offers one measure of their cultural value (Martin 2010). Plants that are ecologically abundant are also more accessible to community members and are therefore used for multiple purposes (Lucena et al 2007); similar findings have been reported by Phillips and Gentry (1993) for all plants and Maldonado et al (2013) for particular use categories. In remote high-altitude areas, 85% of Nepalese depend on plants for primary health care (Kunwar and Bussmann 2008), but we found a low number of plant species and a low number of health-related uses for plants. Possible

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explanations for this might be, first, that we focused only on woody plants, which are generally less frequently used as remedies than herbaceous species (Stepp and Moerman 2001; Monigatti et al 2012). Second, harvesting and selling medicinal plants is a sensitive topic in the MCA so study participants may have avoided mentioning them. There is some tension between NTNC and villagers regarding illegal and overharvesting of medicinal plants for commercial purposes.

Study participants used a high number of woody plant species for cooking and heating fuel, demonstrating both their reliance on these species and their flexibility in choosing among them. Participatory mapping exercises with Gurung men and women have highlighted many sources of fuelwood (Shrestha and Medley 2016), and their use of many species may lessen pressure on any particular species (cf. Medley and Kalibo 2007 for Mt Kasigau, Kenya) and provide greater opportunities to address resource shortages through afforestation (Nagendra 2007). *A. nepalensis* is planted as a fuelwood resource in areas prone to landslides.

For the Gurung villages, oak–laurel and kharsu oak stands at about 2400 m have the highest diversity of plant uses and plant-use categories. Our findings support Himalaya research that substantiates the importance of these mixed temperate forests for human livelihoods (Negi 2000). Oak forests, although varied across the Himalaya, show potential for regrowth that maintains diversity under resource extraction, as our study suggests, but occur in most heavily human populated montane areas with a long history of local and external demands on forest resources (Singh and Singh 1986).

Similarly, the absence of blue pine (*P. wallichiana*) forest around Ghattekhola village suggests a lack of access to resources from that forest community type, and this discovery during the mapping exercise provided a unique opportunity for collaborative conversations and learning about the spatial distribution of forest resources. Of the 4 villages, Ghattekhola's residents had the greatest difficulty accessing plant resources, taking 4–5 hours to reach the nearest forest patch. Reforestation programs could directly address their resource needs and alleviate the stress on the forests of nearby Sano Philim, which the residents of Ghattekhola currently visit to harvest blue pine and other conifer species (*Larix himalaica* and *A. spectabilis*) for use in construction. Residents of Aanga similarly complained that their tall oaks and pines were being harvested by residents of Thulo Philim.

Implications for conservation

Although debate continues over the effective integration of local and scientific knowledge, they show significant potential to contribute to biodiversity conservation (Huntington 2000; Reid et al 2006; Bohensky and Maru 2011). Our study highlights opportunities for the NTNC to better incorporate the knowledge and perspectives of Gurung people who rely on forest resources, and also to better engage them in collaborative planning and management of forests. Such collaboration can be further explored through conservation planning approaches such as adaptive collaborative management, which provides a framework for integrating different forms of knowledge, conducting joint analyses, and adjusting conservation and management strategies based on feedback from shared learning outcomes (Armitage et al 2009). Our study emphasized a participatory mixed-method approach that began collaboration at the initial research stage. For instance, the data collection process required hours of field survey work with local informants to jointly assess forest community types, plant use, and resource availability. Important research outcomes included collaboration on a pictorial plant guidebook for the region and a joint meeting of study participants and the NTNC at the end of the field research in January 2013. This meeting facilitated a discussion of the joint contributions of ecological and ethnobotanical knowledge toward the conservation management goals. Viewing montane forest diversity patterns through the eyes of resource users makes conservation efforts more relevant, adaptive, and meaningful.

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