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Research Article

Forest Resource Use Pattern in Fringe Villages of Barsey *Rhododendron* Sanctuary and Singalila National Park of Khangchendzonga Landscape, India

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Forests in the Barsey-Singalila transboundary area under Khangchendzonga landscape (KL) are facing pressures of resource uses. Despite continuous utilizations, complete data are lacking from the ground level. Socioeconomic, demographic, and forest use data were obtained by interviewing 233 households across two study locations. Forest product market survey was undertaken to determine prices of forest products. Resource dependence index was (0.60) high for both the locations. *Alnus nepalensis* is highly preferred fuel species with probability of use (0.791), and *Rhododendron arboreum* with probability of use (0.09) is considered as least preferred species. Relatively bigger village with more population is aggravating utilization pressures. Resource use at Gorkhey-Samanden is low (20% in case of fuelwood) as compared to the use at Ribdi-Bhareng (80% for fuelwood). Only preferred medicinal plants or wild edibles, namely, *Yushania maling* are collected regardless of their availability for fuelwood and other uses, which is causing more pressure on a small group of plants. A huge shortfall between resource demand and production indicates the possible extraction of resources from surrounding reserve forests. The results provide significant information on peoples dependency on forest resources and may be utilized for developing forest conservation policies for enhanced ecosystem services and livelihoods in the region.

1. Introduction

Forest is an essential component of various ecosystem services. Local people depend on forest resources for various products such as fuel wood, construction materials, medicine, and food [1]. Globally, it is estimated that between 1.1 billion and 1.7 billion people depend to varying degrees on forests for their livelihoods, and about 200 million indigenous communities are almost fully dependent on forests [2]. It is estimated that 20–25% of rural peoples' income is obtained from environmental resources in developing countries [3] and act as safety nets in periods of crisis or during seasonal food shortages [4, 5].

While in rural India, nearly 275 million people are directly dependent on forests for sustaining their livelihood [6]. Forest and people are inextricably linked in India, and around 350–400 million (40%) people are dependent on forest resources [7]. About 70% of Indian population lives in rural areas, and most of them have either agriculture or forest-based economy [8]. Their dependency on the forest resource is still high due to easy access, simple use, and lack of economically viable options [9]. Demand and consumption of fuelwood is not increasing over last decades as compared to the rate estimated earlier in 1980s, and it is still valid in rural areas [10]. The underutilized wild edible bioresources can play a significant role in rural development, poverty alleviation, livelihood enhancement, and nutritional security of local communities through bioprospecting with application of suitable scientific interventions [11–14].

Barsey-Singalila transboundary area within Khangchendzonga landscape (KL) houses unique ethnic and social groups with rich traditional knowledge on bioresource utilization [15]. Over the years, human pressure is exerted upon this transborder area for collection of basic subsistence materials, viz., fuelwood, fodder, construction timber, and nontimber forest produces (NTFPs). The dwelling community in the region employs different farming and livestock practices and also depends on forest resources for regular income generation. Hence, a comprehensive information on resource utilization patterns is required across state's border of KL. Also, to assess environmental impacts posed upon from the intervention is greatly sensed. Therefore, we planned to assess indigenous resource use patterns and people's dependency on bioresource needs. The study principally highlights on the resource availability, their use patterns, demand, and people's dependency on natural resources, for setting conservation priorities and livelihood security as apparent from the assessment.

2. Materials and Methods

2.1. Study Sites. Singalila National Park (SNP) having 78.6 km^2 area is located on the Singalila Ridge at an altitude of 7000 m asl, in the Darjeeling district of West Bengal. It is famous for trekking route to Sandakphu that runs through it. The park was previously declared a wildlife sanctuary in 1986. The region had long been used as the trekking route from Manebhanjang to Sandakphu (the highest peak of West Bengal and Phalut). The trek along the Singalila Ridge to Sandakphu and Phalut is one of the most popular ones in the Eastern Himalaya, due to the grand vistas of the Khangchendzonga range, and the Everest range which can be seen from the ridge and also for the seasonal wildflower blooms and birding.

Barsey *Rhododendron* Sanctuary (BRS) covers an area of 104 km^2, established in 2004 in the Singalila Ridge in western Sikkim. It borders on Nepal to the west and on the state of West Bengal to the south across the Rambong Khola stream. There are three points of entry to this sanctuary from Hilley, Dentam, and Soreng. Tourists generally prefer Hilley, since it is approachable by road too. The bridle path from Hilley to Barsey is a favorite amongst tourists especially during the *Rhododendron* flowering season. The faunal value of BRS includes leopard cat, Himalayan Yellow throated Marten, Himalayan Palm Civet, and many diverse species of birds. Two villages were selected for the present study from the Barsey-Singalila transboundary area, namely, Ribdi-Bhareng surrounding the BRS (Sikkim) and Gorkhey-Samanden (Darjeeling district, West Bengal) surrounding the SNP (Table 1).

Gorkhey-Samanden, a forest village located at an altitude of 2286 m asl, is the remotest village situated in the close proximity to the SNP (Darjeeling) in the north and BRS (Sikkim) in the east connected by an interstate border (Figure 1). It is bestowed with rich biodiversity providing a wide range of ecosystem services and hence bears local significance. The village covers an area of 36 hectares. There are 65 households in the village with a total population of 205 persons comprising of Sherpa, Rai, Chettri, and Tamang communities. Male literacy rate of the village is 64%; whereas, female literacy rate is 52%. Agriculture, livestock, and tourism are major livelihood options of the community. Potato, maize, oat (barley), bean, rayosaag (green leafy vegetable), pea, cabbage, radish, and squash are common crops found. Apart from these, yacon (*Smallanthus sonchifolius*) is recently introduced speciesunder KL programme.

Ribdi-Bhareng, West Sikkim, is a Gram Panchayat Unit (GPU) with a total area of 543 hectares. There are 324 households in the GPU with total population of 1536 persons. Sherpa, Rai, Chettri, Tamang, and Gurung are the main dwelling communities. Male literacy rate of Ribdi-Bhareng is 60% and female 50%. Agriculture and livestock rearing are major occupations of the people in Ribdi-Bhareng. Potato, maize, oat (barley), bean, rayosaag, pea, buckwheat, cabbage, cauliflower, radish, squash, and large cardamom are staple crops cultivated, and cattle are also kept for diary purposes.

2.2. Methods

2.2.1. Survey and Sampling. The socioeconomic survey of the households using semistructured questionnaire formats was carried out. A total of 233 households were surveyed from Gorkhey-Samanden (as site-A, 60 hh) and Ribdi-Bhareng (as site-B, 173 hh). The data were collected through stratified random sampling [16] to select households in the sample villages to collect primary socioeconomic data on types of forest resource consumption, source, frequency, resource demand, and farm production. The forest product market survey was undertaken to determine prices of forest products. In addition, the PRA (including focus group discussions) survey was conducted. In the process, key stakeholders/informants, members of the farming community, ecotourism committee members, government employees, and the panchayat representatives were involved. Preferred fodder species were also documented from the households. Households were asked about the fuelwood, fodder, and other non-timber forest product collection and quantity of biomass that they extracted annually from the forest. Two individuals per household per day were found involved in collection of fuel. Weighed the head loads (bhari) for fuelwood at the entry and exit points of the forest boundary during November–March approximately for 150 days. Forty bharis were sampled in each village during each investigation. Collected amount of each species segregated out of each bundle based on local names and then weighed using a spring balance [17]. Living samples (twig containing leaf and flowers) of each species were locally identified and were later identified scientifically. To measure fuelwood utilization, actual number of hours burnt by a species was divided by the total number of hours that the fuel could have burnt [17]. Additional information were collected using field

Table 1: Detail of the study sites.

Study area	Latitude and longitude	Total no. of households	Total population	Population involved for collection	No. of fuelwood species available
Ribdi Bhareng	27°9′32.14″–27°11′00.77″N 88°4′37.29″–88°07′11.95″E	324	1536	1396	32
Gorkhey-Samanden	27°10′39.26″–27°11′25.83″N 88°04′02.24″–88°04′29.09″E	65	205	178	31

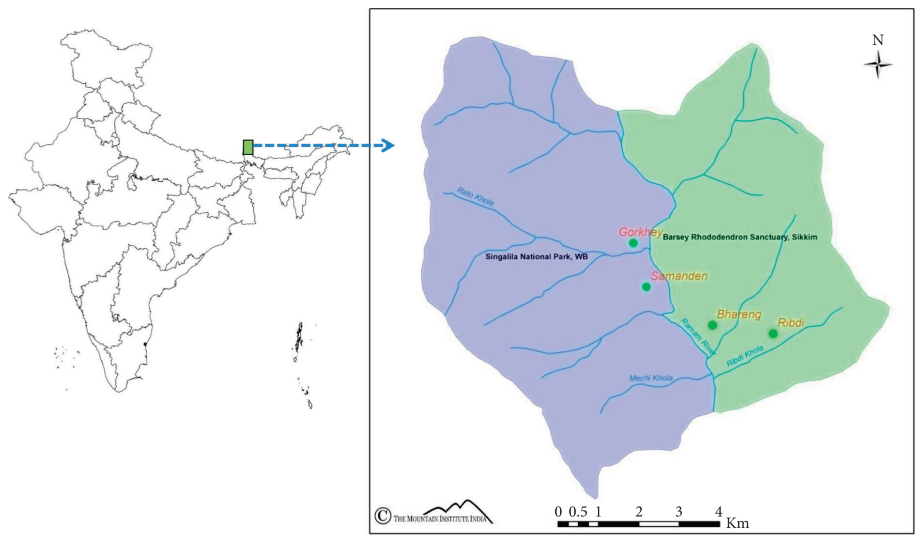

Figure 1: Map of the study area showing the location of study villages in Khangchendzonga landscape, India.

observations and transect walks. Information on price of different NTFPs/wild edibles and medicinal plants were collected through the market survey. The collected data on fuelwood were analysed following [17, 18].

2.2.2. Data Analysis.

$$\text{Total species collected household}^{-1}\text{day}^{-1}\ (C_d) = \text{number of individuals househosld}^{-1}\text{responsible for collection} \quad \&9; \quad \times \text{average collection}\,(A) \tag{1}$$

or

$$A = \frac{T}{N}, \tag{2}$$

where T is the total species collected in all samples, and N is the number of samples.

$$\text{Probability of use (PU)} = \frac{\sum F_i P_i}{\sum P_i}, \tag{3}$$

where F_i is the frequency of collection of a species in the i^{th} site, and P_i is the population of the i^{th} site.

$$\text{Resource use index (RUI)} = \text{total species collection household}^{-1}\text{year}^{-1} \times \text{PU}. \tag{4}$$

Fuelwood consumption among the sites was determined using Sorenson's similarity index [19]:

$$\text{Similarity index (SI)} = \frac{2\text{C}}{\text{A} + \text{B}} \times 100, \tag{5}$$

where C is the amount of fuel collected common in sites (A and B); A is the collection of fuel in site A, and B is the collection of fuel in site B. Shortfall in resource needs and possible extraction are determined on the basis of the information collected.

3. Results

3.1. Resource Availability Status and People's Dependency. With the aim of collecting data on resource base for villages, we carried out the seasonal study on resource extraction and utilization patterns. Results of the studied parameters depicted that fuelwood, fodder, timber, wild edibles, medicinal plants, and litter are the most common forest resources for Ribdi-Bhareng and Gorkhey-Samanden households (Table 2). Regardless of availability status, source of resource would be preferentially private forests (as rural people claim), reserved forest, national parks, and wildlife sanctuaries. We evidenced colloquial activities of tourism practices, forest collections, and grazing from the sites. People have to travel atleast 2–5 kilometers distances everyday to extract the resource. Wherein, the dependency index of studied sites was determined within 0.60.

The fuelwood consumption at Ribdi-Bhareng was recorded slightly higher than Gorkhey-Samanden by 1.5%; farmland production of fuelwood at Ribdi-Bhareng was more than private land fuelwood growth at Gorkhey-Samanden by 80%. This may be due to higher fraction of landholdings possessed by the house of Ribdi-Bhareng. The total number of households at Ribdi-Bhareng is 324 and Gorkhey-Samanden is 65. Likewise, fodder consumption rate was more at Ribdi-Bhareng (17%) than fodder consumption at Gorkhey-Samanden, and in a similar way, the farm fodder production rate at Gorkhey-Samanden was lower than Ribdi-Bhareng (58.3%).

Timber required at Gorkhey-Samanden was found 6 cubic $\mathrm{cm \cdot hh^{-1}\ yr^{-1}}$ which is much higher than the estimated production of 0.1 cubic cm $\mathrm{hh^{-1}\ y^{-1}}$. Similarly, timber demand in Ribdi-Bhareng was recorded 7.5 cubic cm $\mathrm{hh^{-1} \cdot yr^{-1}}$, and the production was 0.2 cubic $\mathrm{cm \cdot hh^{-1} \cdot yr^{-1}}$. On the other hand, litter use at both Gorkhey-Samanden and Ribdi-Bhareng villages was found 10 $\mathrm{kg \cdot hh^{-1} \cdot d^{-1}}$ and 12 $\mathrm{kg \cdot hh^{-1} \cdot d^{-1}}$, respectively. Similarly, production amount was found 7 $\mathrm{kg \cdot hh^{-1} \cdot yr^{-1}}$ for both the villages. NTFP/wild edibles demand at Gorkhey-Samanden was 0.5 $\mathrm{kg \cdot hh^{-1} \cdot d^{-1}}$ and Ribdi-Bhareng 0.4 $\mathrm{kg \cdot hh^{-1} \cdot d^{-1}}$; whereas, production was found half of the amount, i.e., 0.25 $\mathrm{kg \cdot hh^{-1} \cdot d^{-1}}$ for both the above villages. Across the study sites, food stuffs (ration) required were estimated 12 $\mathrm{kg \cdot hh^{-1} \cdot month^{-1}}$ for a family having 6 members in each. Per capita crop production was estimated 3 $\mathrm{kg \cdot month^{-1}}$ for a family.

3.2. Fuelwood Collection, Probability of Use (PU), and Resource Use Index (RUI). Habit and mean collection (kg $\mathrm{sample^{-1} \cdot day^{-1}}$ and kg $\mathrm{sample^{-1} \cdot yr^{-1}}$) for common fuelwood species are presented in Table 3. Most species used for fuel are regarded as tree species. Mean collection for *Arundo donax* (1.68 $\mathrm{kg \cdot sample^{-1} \cdot day^{-1}}$) is found to be the most collected species followed by Quercus lamellosa (1.62 $\mathrm{kg \cdot sample^{-1} \cdot day^{-1}}$) and least for Tsuga dumosa and Ankhle (0.11 $\mathrm{kg \cdot sample^{-1} \cdot day^{-1}}$). For yearly extrapolation, Aundo donax (252 $\mathrm{kg \cdot sample^{-1} \cdot year^{-1}}$) showed the most collected species followed by *Quercus lamellosa Sm.* (243 $\mathrm{kg \cdot sample^{-1} \cdot year^{-1}}$) and the least to Alnus nepalensis D. Don (241.5 $\mathrm{sample^{-1} \cdot year^{-1}}$). Probability of use (PU) is maximum for *Arundo donax* (0.813) followed by *Alnus nepalensis* (0.791), *Dendrocalamus hamiltonii* (0.745), and *Castanopsis tribuloides* (0.7) and least in *Rhododendron arboreum* (0.09).

Resource extraction processes were studied for fuel, fodder, timber, NTFPs/wild edibles, litter, and crop (Table 4). Our survey revealed that per year fuelwood consumption at Ribdi-Bhareng is (7409.5 $\mathrm{kk \cdot hh^{-1}}$), fodder (6570 $\mathrm{kk \cdot hh^{-1}}$), and NTFPs (146 $\mathrm{kg \cdot hh^{-1}}$) and Gorkhey-Samanden fuelwood is (7300 $\mathrm{kk \cdot hh^{-1}}$), fodder (5475 $\mathrm{kg \cdot hh^{-1}}$), and NTFPs (182.5 $\mathrm{kg \cdot hh^{-1}}$). Resource demand is compared with the resource production as shown in Table 5. Demand of fuelwood (2393.27 $\mathrm{ton \cdot yr^{-1}}$) and fodder (2122.11 $\mathrm{ton \cdot yr^{-1}}$) at Ribdi-Bhareng was comparatively more than what is recorded from Gorkhey-Samanden (fuelwood 445.3 $\mathrm{ton \cdot yr^{-1}}$ and fodder 333.98 $\mathrm{ton \cdot yr^{-1}}$). Considering the fact that wood biomass is required for construction purposes such as house and goths/cowshed, such is evident from timber requirement at Ribdi-Bhareng (2422.5 cft/yr) and also production (64.6 cft/yr) thereby leading to shortfall amount (2357.9 cft/yr). Fuelwood demand in Gorkhey-Samanden was (445.3 $\mathrm{ton \cdot yr^{-1}}$), whereas production was (0.12 $\mathrm{ton \cdot yr^{-1}}$). As per the primary survey of the villages, the fuel consumption was 418.86 ton, and the annual fuel availability was estimated as 211.03 ton, which indicates a deficit of 207.83 ton. Per family fuel consumption was found 52.53 kg which varies seasonally (summer, 17.28 kg and winter, 35.25 kg).

3.3. Fodder Use. Farm animals in Barsey-Singalila are rearing by two means stall feeding and open grazing. Open grazing in forest sites has been banned in Sikkim under state's revised grazing policy, 2005 (remained effective from 2010), although illegal grazing inside forests occur. But the animal percentage meant for stall feeding is more (80%). While studying the fodder preferences, 8 most preferred species, 12 preferred species, and 6 least preferred species were found for both Ribdi-Bhareng and Gorkhey-Samanden villages (Table 6).

3.4. NTFP Use. Varying degrees of NTFP use (as high, medium, and low) and availability status (abundant, moderate, and rare) were noted. People's dependency (high, medium, and low) and market prices of various wild edibles, NTFPs, and medicinal herbs were studied as shown in Table 7. It is observed that *Diplazium* sp. is priced to a low of only Rs. 10/bundle, and *Nardostachys jatamansi* fetched the highest price of Rs.300. Some of the medicinal plants species are available seasonally/annually either in community forests (CF), reserve forest (RF), protected forests (PF), khasmal forest (KF), and agroforests (AF) as presented in Table 8.

4. Discussion

The forests preserve the biological diversity as well as provide the natural wealth to the human being. But forests are still degrading day by day due to exponential population growth,

Table 2: Different sources, availability status, and people's dependency on local resources found in Barsey-Singalila site.

Settlements	Resource types	Source	Availability status	Availability distance (km)	Dependence index (*DI)
Ribdi Bhareng	Firewood, fodder, wood/poles (fencing), NTFPs, medicinal herbs, and litter	Wildlife sanctuary, reserved forests, khasmal forests, and private forests	Medium	2–4	0.60
Gorkhey-Samanden	Firewood, fodder, wood/poles, NTFPs and medicinal herbs, and litter	National park, reserved forests, and khasmal forests	Low	2–5	0.60

*Dependence index (DI) is calculated on a scale of 0-1.

Table 3: Amount of collection probability of use (PU) and resource use index (RUI) for important fuelwood species in Barsey-Singalila.

Species (local name)	Habit	Collection (mean)			
		$Kg{\cdot}sample^{-1}{\cdot}d^{-1}$	$Kg{\cdot}sample^{-1}{\cdot}yr^{-1}$	Probability of use (PU)	Resource use index (RUI)
Alnus nepalensis D.Don (Uttis)	T	1.61	241.5	0.791	189.8
Beilschmiedia roxburghiana Nees (Tarsing)	T	0.19	28.5	0.339	81.3
Betula cylindrostachys Wall. ex Diels (Saur)	T	0.45	67.5	0.632	151.6
Castanopsis indica (Roxb. ex Lindl.) A.DC. (Dhalne Katus)	T	1.44	216	0.678	162.7
Castanopsis tribuloides (Sm.) A. DC. (Musurey Katus)	T	1.33	199.5	0.7	168
Chukrasia tabularis A.Juss. (Bogipoma)	T	1.21	181.5	0.271	65.0
Cryptomeria japonica (Thunb. ex L.f.) D.Don (Dhuppi)	T	0.25	37.5	0.293	70.3
Dendrocalamus hamiltonii Nees & Arn. ex Munro (Bans)	T	1.23	184.5	0.745	178.8
Edgeworthia gardneri (Wall.) Meisn. (Argeli)	S	0.57	85.5	0.542	130.0
Engelhardtia spicata Lechen ex Blume (Mauwa)	T	0.45	67.5	0.587	140.8
Eurya acuminata DC. (Zhingane)	T	0.85	127.5	0.519	124.5
Leucosceptrum canum Sm. (Ghurpis)	T	0.62	93	0.565	135.6
Lithocarpus pachyphyllus (Kurz) Rehder	T	0.12	18	0.18	43.2
Lyonia ovalifolia (Wall.) Drude (Angaree)	T	0.43	64.5	0.203	48.7
Macaranga indica Wight (Malata)	T	0.66	99	0.361	86.6
Macaranga denticulata (Blume) Müll. Arg. (Sanomalata)	T	0.13	19.5	0.384	92.1
Machilus edulis King ex Hook.f. (Rani Kawlo)	T	0.31	46.5	0.406	97.4
Maesa chisia Buch.-Ham. ex D. Don (Bilaune)	T	0.24	36	0.406	97.4
Nyssa javanica (Blume) Wangerin (Lekhchilaune)	T	0.14	21	0.293	70.3
Prunus cerasoides Buch.-Ham. ex D.Don (Paiyun)	T	0.54	81	0.497	119.2
Lithocarpus fenestratus (Roxb.) Rehder (Arkahulo)	T	0.59	88.5	0.18	43.2
Quercus lamellosa Sm. (Bajranth)	T	1.62	243	0.158	37.9
Quercus lineata Blume (Phlant)	T	0.98	147	0.135	32.4
Rhododendron arboretum Sm. (Laligurans)	T	0.45	67.5	0.09	21.6
Schima wallichii Choisy (Chilaune)	T	0.86	129	0.429	102.9
Symplocos theifolia (Kharane)	T	0.23	34.5	0.316	75.8
Symplocos sumuntia Buch.-Ham. ex D.Don (Kholme)	T	0.12	18	0.339	81.3
Tsuga dumosa (D.Don) Eichler (Thingre salla)	T	0.11	16.5	0.113	27.1
Viburnum nervosum D.Don (Ashare)	T	0.67	100.5	0.226	54.2
Meliosma arnottiana (Wight) Walp (Dabdabe)	T	0.13	19.5	0.18	43.2
(Aankhle)	T	0.11	16.5	0.135	32.4
Arundo donax (Narkat)	S	1.68	252	0.813	195.1

T, tree; S, shrub.

Table 4: Traditional resource use pattern in the Barsey-Singalila site.

Resource	Extraction process	Species under use	Frequency	Average consumption kg/hh/d	Average consumption kg/hh/yr
Ribdi Bhareng					
Fuelwood	Felling, lopping, and collecting	*Eragrostis gangetica* (Bansho/Ghini), *Persicaria chinensis* (Ratnaulo), *Persicaria chinensis* (Ratnaulo), and *Strobilanthus* sp. (Ankhley)	Morning 2-3 times a day	20.3	7409.5
Fodder	Felling, chopping, and collecting		Morning 2-3 times a day	18	6570
*Timber	Felling and sawing		2-3 times in between 5 and 10 years	—	7.5 cm^3
NTFPs and medicinal plants	Felling, chopping, umbel picking, uprooting, and collecting		Morning 2-3 times a week	0.4	146
Litter	Collecting		>2-3 times a day	12	4380
Gorkhey-Samanden					
Fuelwood	Felling, lopping, and collecting	*Eragrostis gangetica* (Bansho/Ghini), *Persicaria chinensis* (Ratnaulo), *Persicaria chinensis* (Ratnaulo), and *Strobilanthus* sp. (Ankhley)	Morning 2-3 times a day	20	7300
Fodder	Felling, chopping, and collecting		Morning 2-3 times a day	15	5475
Timber	Felling and sawing		2-3 times in between 5–10 years	—	6 cm^3
NTFPs and medicinal plants	Felling, chopping, umbel picking, uprooting, and collecting		Morning 2-3 times a week	0.5	182.5
Litter	Collecting		>2-3 times a day	10	3650

*Timber is required in between 10 and 15 years for house construction.

Table 5: Annual resource production and actual demand in study villages under Barsey-Singalila range.

Resource	Ribdi Bhareng				Gorkhey-Samanden			
	Demand (ton/cm^3/yr)	Production (ton/yr)	S	PE	Demand (ton/cm^3/yr)	Production (ton/yr)	S	PE
Fuelwood	2393.27	3.23	2390.04	1434.02	445.3	0.12	445.18	267.11
Fodder	2122.11	46.51	2075.6	1245.36	333.98	3.66	330.32	198.19
Timber	2422.5	64.6	2357.9	1414.74	366	6.1	359.9	215.94
NTFPs	47.16	29.47	17.69	10.61	11.13	5.7	5.43	3.26
Litter	1414.74	2.26	1412.48	847.49	222.65	0.43	222.22	133.33
Food crops*	279.07	69.77	209.3	125.58	52.70	13.18	39.52	23.71

DI, dependency index from Table 1. Shortfall (S) = $D - P$. Possible extraction (PE) = $S \times$ DI. *Purchasing of food crops/items.

poverty, and lack of awareness about the ecosystem services [8]. More than 350 million people were living inside or on the fringes of forests across the world, out of which 60 million were largely dependent for sustenance [6]. Forests in most developing countries are under anthropogenic pressure from resource use by marginalized communities for subsistence [7, 20, 21]. The condition is considered more perilous in Asia and Africa, where loss of forests during a ten-year period in the later part of the 20th century was estimated to 163 million ha, of which 154 million ha (94.5%) was in the tropics alone [22].

Resource use data suggests that resource need is collected from a certain distance in the forest area which will be far from the houses. The dependency index of study sites was found much higher than the dependency rate of households as estimated in the midhills of eastern Nepal (40%) [23]. The households with low income and small fragmented land are more dependent on the forest resources [24]. Type and degree of dependence varies from place to place. It is highest among the families living within forest areas. Such families (about 10% of the households) have no or very small landholdings. Others who significantly depend for their household and day to day requirements as well as for certain specific (such as medicinal) uses on neighbouring forests (about 50%) include not only those principally associated with agriculture or allied activities but also involved with forests one way or the other [25].

Whereas, the average fuelwood consumption in the area is comparatively higher than the fuelwood consumption

Table 6: Preference-wise ranking of fodder species in study sites.

Most preferred (local name)	Preferred (local name)	Least preferred (local name)
Ribdi Bhareng		
Arundo donax L. (Narkat)	*Pennisetum purpureum* Schumach. (Napier)	*Sida acuta* Burm. (Balu)
Lithocarpus pachyphyllus (Kurz) Rehder (Bantey)	*Eragrostis gangetica* (Roxb.) Steud. (Bansho/Ghini)	*Litsea* sp. (Timmur)
Litsea elongata (Nees) Hook (Pahenley)	*Persicaria chinensis* (L.) H. Gross (Ratnaulo)	*Rubus* sp. (Berry)
Sida acuta Burm. (Balu)	*Machilus* sp. (Kawlo)	*Ficus elastica* Roxb. (Lishey)
Acer calcaratum Gagnep. (Kapshee)	*Arundo donax* L. (Narkat)	*Zea mays* L. (Maize residue)
Meliosma arnottiana (Wight) Walp (Dabdabe)	*Strobilanthus* sp. (Ankhley)	*Eragrostis gangetica* (Roxb.) Steud. (Bansho/Ghini)
Litsea sp. (Timmur)	*Quercus lineata* Blume (Phlant)	
	Evodia fraxinifolia (Hook.) Benth. (Khanakpa)	
	Yushania maling (Gamble) R.B. Majumdar & Karthik.(Malingo)	
Cissus elongate Roxb. (Charcharey lahara)	*Amiley ghans*	
	Toona ciliata M. Roem. (Tuni)	
	Actinidia strigosa Hook. F. & Thomson ex Benth (Thekiphal)	
Gorkhey-Samanden		
Arundo donax L. (Narkat)	*Pennisetum purpureum* Schumach. (Napier)	*Sida acuta* Burm. (Balu)
Lithocarpus pachyphyllus (Kurz) Rehder (Bantey)	*Poa* sp. (Bansho/Ghini)	*Litsea* sp. (Timmur)
Litsea elongata (Nees) Hook (Pahenley)	*Persicaria chinensis* (L.) H. Gross (Ratnaulo)	*Rubus* sp. (Berry)
Sida acuta Burm. (Balu)	*Machilus* sp. (Kawlo)	*Ficus elastica* Roxb. (Lishey)
Acer calcaratum Gagnep. (Kapshee)	*Arundo donax* L. (Narkat)	*Zea mays* L. (Maize residue)
Meliosma arnottiana (Wight) Walp. (Dabdabe)	*Strobilanthus* sp. (Ankhley)	*Eragrostis gangetica* (Roxb.) Steud. (Bansho/Ghini)
Litsea sp. (Timmur)	*Quercus lineata* Blume (Phlant)	
	Evodia fraxinifolia (Hook.) Benth.	
Cissus elongate Roxb. (Charcharey lahara) (Khanakpa)	*Yushania maling* (Gamble) R.B. Majumdar & Karthik.(Malingo)	
	Amiley ghans	
	Toona ciliata M. Roem.(Tuni)	
	Actinidia strigosa Hook. F. & Thomson ex Benth (Thekiphal)	

1, abundant; 2, common; 3, rare.

amount as reported for Garhwal Himalaya [26] but lesser than the amount measured in Kedarnath region [27]. So, it honestly proves that pressure on resources is considerably high. Yearly production of the resource was also comparatively much lesser than the requirement for households of both the study sites, and this result can be compared with a study held in Niti valley where fuelwood consumption was much lower than the consumption amount of other greater Himalayan villages [28]. The average fuelwood consumption data is also compared with data in Kumaon villages, where per capita consumption amount was estimated to 3.14 kg/day [29]. Since fuelwood collection forms the highest and the most frequent use of forests followed by timber and fodder collection for livestock [25]. Although *Arundo donax* shows high RUI, it is available at farmland. *Alnus nepalensis, Dendrocalamushamiltoni*, and *Castanopsis tribuloides* having high RUI are available at the forest including *Alnus nepalensis* depicting high pressure on the species. Definitely, these species having high PU show preferences in the villages. Thus, a comparatively larger village with more population will aggravate utilization pressures.

Resource production is far lesser than the demand as evident from the present survey. The area is characterized by sparse vegetation cover, low primary productivity, and short growing season and is thus highly susceptible to irreversible changes of natural habitats [28, 30]. A huge shortfall in resource availability predicts the possible extraction of resources from the surrounding forests (namely, the khasmal forests, protected areas, and agroforestry areas). And the whole can also be compared with the total available fodder in Central Himalayan village [31].

There is a huge gap between timber demand and production which is required for construction of house and goths/cowshed, and such case is evident from timber demand at Ribdi-Bhareng and wood production rate, thereby, leading to huge shortfall. Considering the fact that a very small fraction of firewood comes from the agriculture fields, various resources demand and production in the study villages are attributed to production and utilization patterns.

Table 7: NTFPs/wild edibles (1 US$ = Rs. 72 approx.).

Species (local name)	Usage	Degree of use	Availability status	People's dependency	Market price (Rs·kg^{-1})
Polygonum molle D. Don (Thotnee)	Fodder, NTFP, and edible	Low	Abundant	High	—
Artemisia vulgaris L. (Titeypati)	NTFP and medicine	High	Abundant	High	—
Zanthoxylum sp. (Eirmong)	NTFP and medicine	Low	Abundant	Low	50.0
Himalayacalamus hookerianus (Munro) Stapleton (Paraeing)	Roofing, fencing, and NTFP	High	Moderate	High	50.0
Yushania maling (Gamble) R. B. Majumdar & Karthik.(Malingo)	Roofing and NTFP	Medium	Rare	High	80.0
Astilbe rivularis Buch.-Ham. ex D.Don (Budookhati)	Medicine	Low	Rare	Medium	30.0
Diplazium sp.(Ninguro)	NTFP and edible	Medium	Abundant	High	10.0
Evodia fraxinifolia (Hook.) Benth. (Khanakpa)	NTFP and remedial	Low	Rare	High	—
Heracleum wallichii DC (Chimphing)	NTFP and medicine	Low	Rare	High	30.0
Litsea cubeba (Lour.) Pers. (Siltimur)	NTFP and medicine	Medium	Abundant	High	54.0
Pentapanax castanopsidicola Hayata (Chinday)	NTFP and edible	Medium	Abundant	Medium	30.0
Rhododendron arboreum Sm. (Gurans)	NTFP and medicine	Medium	Abundant	High	—
Rubus ellipticus Sm. (Aiselu)	NTFP and edible	Low	Abundant	Medium	—
Urtica dioica L. (Sisnu)	NTFP, fibre, and edible	High	Abundant	High	25.0
Zanthoxylum acanthopodium DC. (Bokey timur)	NTFP, edible, and medicine	Low	Rare	Medium	20.0
Actinidia strigosa Hook. F. & Thomson ex Benth (Thekiphal)	NTFP and edible	Medium	Rare	Medium	20.0
Pyrus pashia Buch.-Ham. ex D.Don (Jangali Mel)	NTFP, edible, and medicine	Medium	Rare	Medium	20.0
Agaricus sp. (Local)	NTFP and edible	High	Rare	High	150.0
Arisema sp. (Gurbo)	NTFP and edible	Low	Rare	Medium	30.0
Castanopsis indica (Roxb. ex Lindl.) A.DC. (Dhalne Katus)	NTFP and edible	Low	Rare	Medium	20.0

The higher price is attributed being the species grow in high altitudes and in rare status [32]. Similarly, mushroom considered as valuable wild edible fetch higher market cost. This income can be compared with the value-added products of most selected wild edibles which derived maximum economic returns in Garhwal Himalaya for *Hippophae salicifolia* followed by *Rhododendron arboreum* and *Spondias pinnata* and minimum for *Myrica esculenta* [33]. Communities of both the villages use local medicinal plants for treatment of health problems related to indigestion, antispasmodic, chronic fever, dysentery, and influenza, for which different parts (e.g., root, fruit, leaf, and sometimes entire plant) are used. These medicinal plants are found to be distributed within an elevation range between 800 and 3600 m asl in the Himalaya [34]. Preferred species are collected regardless of their availability for fuelwood and other uses, which is causing high pressure on a small group of plants. Marketing of medicinal herbs is inefficient, informal, secretive, and opportunistic. As a result, the raw material supply situation is shaky, unsustainable, and exploitative, which in turn leads to depletion of the resource base exploiting of the rural people (who are the real stewards of the resource), adulteration, and nonavailability of quality herbal drugs for domestic consumption as well as for exports [35, 36]. In a conclusion, local ecosystem suffers from shortage of suitable resource management policies in one; similarly, delay in implementation of associated policies may also result in gradual loss of biodiversity in another. The regional initiatives taken by G. B. Pant National Institute of Himalayan Environment (NIHE) under Khangchendzonga Landscape Conservation and Development Initiative- (KLCDI-) India programme have been widely appreciated. KLCDI is one of such transboundary programme where partner countries may work together taking the above approaches.

5. Conclusion

Transboundary areas are more vulnerable in terms of encroachment such as tourist trekking, carrying of business items, animal grazing, and collection of medicinal/wild plants, as evidenced in the Barsey-Singalila transboundary area. Sustainable use of the resource in the area is much required so that livelihood of the local people be improved. Production using local and productive fodder species should be emphasized. Fuel, fodder, and wild edibles including medicinal herbal are diverse, but there may a great threat to those species of protected areas. Our results emphasized the need for regular assessment of forest resources, particularly in protected areas. The afforestation of degraded, uncultivated, and marginal lands through high-quality fuel species

Table 8: Medicinal herbs from the study sites.

Species (local name)	Elevation (m)	Habit	Availability time	Parts use	Colour/ Taste	Usage	Consumption (kg $hh^{-1} \cdot yr^{-1}$)	Source
Acorus calamus L. (Bonjho)	800–2500	Herb	Perennial	Root	White/ bitter	Bone fracture	5	CF
Artemisia vulgaris L. (Titeypati)	800–2000	Herb	Perennial	Root and leaves	Green/ bitter	Antiseptic and asthma	400	F/RF
Astilbe rivularis Buch.-Ham. ex D.Don (Budookhat)	1600–3300	Shrub	Perennial	Root	Green/ bitter	Dysentery	200	RF
Eupatorium cannabinum L. (Banmara)	800–2500	Herb	Perennial	Leaf	Green/ bitter	Bleeding	—	AF/CF
Evodia fraxinifolia (Hook.) Benth. (Khanakpa)	1500–2500	Tree	August	Fruit	Green/ bitter	Indigestion	500	RF
Heracleum wallichii DC. (Chimphing)	1500–2500	Herb	September	Fruit	Red/bitter	Influenza	600	KF
Centella asiatica (L.) Urb. (Dalleypat)	1000–2500	Herb	Perennial	Leaf	Sour	Throat pain	—	Farm/ AF
Nardostachys jatamansi (D.Don) DC. (Jatamansi)	3600–4800	Herb	Perennial	Root	Green/ bitter	Antispasmodic	100	CF/AF
Swertia chirata Buch.-Ham. ex Wall (Chirawto)	1600–2600	Herb	July	Whole plant	Green/ bitter	Chronic fever	1000	PF
Amomum subulatum Roxb. (Elaichi)	500–1900	Herb	October	Fruit	Grey/ sweet	Spice	500	KF/AF
Elaeocarpus sp. (Rudraksha)	1000–1800	Tree	November	Fruit	Green/ sour	Stomachache	600	KF/AF
Entada sp.	1500–2500	Tree	Perennial	Flower	Alkaloid	Indigestion	50	KF/AF
Cinnamomum tamala (Buch.-Ham.) T.Nees & Eberm. (Tejpat)	800–2500	Tree	Perennial	Leaf	Green/ tasteless	Spices	100	CF/AF
Thysanolaena latifolia (Roxb. ex Hornem.) Honda	300–4800	Shrub	August	Root	White/ tasteless	Diarrhea	1000	PF/AF
Zanthoxylum sp. (Timbur)	1600–2600	Tree	November	Fruit	Red/hot	Antispasmodic	500	RF/KF
Phyllanthus emblica L. (Amla)	500–1500	Tree	Perennial	Fruit	Green/ sour	Stomach problems	600	KF/AF
Rumex nepalensis Spreng. (Halhale)	800–1800	Herb	Perennial	Root	Tasteless	Dysentery	—	Farm/ AF
Rhus succedanea L. (Arkhol)	800–2500	Tree	November	Fruit	Grey/sour	Dysentery	100	CF/AF

RF, reserved forest; PF, protected forest; *F,* farm.

in the villages might reduce pressure. Energy value of these species also needs to be determined.

The study further suggests that providing alternate and nonconventional energy sources such as solar cookers and fuel efficient portable ovens to the inhabitants at subsidized rates could reduce the pressure on nearby forests. However, the local government has supported the community people through supplying LPG stoves and cylinders at free of cost which may not be in sufficient quantity. Besides, judicious harvest of resources considering the production rate is ever appreciated. Similarly, government policies involving resource management can impact development processes. Further alternative energy sources are to be generated such as the use of biobriquettes (matula) as fuelwood.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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