Assessment of natural resources use patterns: a case study along a trekking corridor of Sikkim Himalaya, India

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In the Himalayas, subsistence largely depends upon resources derived from natural forests due to the free and easy access to these and simplicity in their use. Sikkim has 43% of its total geographical area under forest cover, of which 34% is under dense forests. The burgeoning human population and family fragmentations are exerting a tremendous pressure on the natural resources to meet the requirements of food, fuel, fodder, timber, and other human needs. In recent years, tourism has increased manifolds in Sikkim, which has been one of the major factors behind destruction of forests. Irrational use of natural resources has resulted in the lowering of forest quality and shortage of resources. As a result, people have started using less-valued species as firewood and fodder. This study deals with bioresources use pattern by the community and tourism enterprises along a trekking corridor in the Sikkim Himalaya, with special reference to firewood, fodder, and timber.

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Introduction

The Himalayan forest resources have been widely used to provide food, fuel, and feed for livestock, construction material, medicines, etc. by mountain communities since time immemorial. This is because these resources are free and easy to access (Bajracharya [1983]; Eckholm, Foley, Banard, *et al.* [1984]; Fox [1984]; Blaikie [1985]; Mahat, Griffin, and Sheperd [1987]; Sundriyal, Sharma, Rai, *et al.* [1994]; Sundriyal and Sharma [1996]; Chettri, Sharma, Deb, *et al.* [2002]). In the Himalayas, commercial resources are beyond reach of the local communities due to difficulty in their access, and the high prices and limited supply (Sharma, Sundriyal, Rai, *et al.* [1992]; FAO, [1994]). Most tropical forests were lost during the past century due to unsustainable levels and ways of exploitation by the local communities, government agencies, and traders (Brown and Lugo [1982]; Brown, Gillerpie, and Lugo [1991]; WRI and IIED [1987]; Thapa and Weber [1990]). The burgeoning human and livestock population in the rural areas is exerting an immense pressure on bioresources. In the process, overexploitation and improper use of these resources have resulted in the disappearance of forests, erosion of soil, and deterioration of fragile ecosystems (Thapa and Weber 1990; Sundriyal, Sharma, Rai, *et al.* 1994; Sundriyal and Sharma 1996; Chettri, Sharma, Deb, *et al.* 2002). Thus, human disturbances have been noted as the single-largest cause for loss of biodiversity, and the remaining forests are vulnerable to deterioration and degradation due to their indiscriminate use (Hannah, Carr, and Lakerani 1995; Chettri, Sharma, Deb, *et al.* 2002).

A total of 43% of Sikkim's geographical area is under forest cover, of which 34% is under dense forests (Government of Sikkim, RRSSC, and ISRO 1994). A majority of people in Sikkim depend upon forests for firewood, fodder, and timber, a substantial portion of which comes from natural forests. Firewood is used by the local community for different purposes, such as cooking, preparing animal feed, house and water heating, local wine and beer preparation, and for festivals. About five tonnes/hectare of woody biomass is removed for firewood annually from forests (Sharma, Sundriyal, Rai, *et al.* 1992). A large number of households also depend upon livestock for which they, in turn, depend upon forests for fodder. Likewise, most houses are constructed from timber collected from surrounding forests. Fragmentation of families leads to construction of many new houses each year, entailing a substantial consumption of woody biomass from the forest (Sundriyal, Sharma, Rai, *et al.* 1994). The change in land use pattern, resource exploitation, and weak conservation measures have evoked a concern for sustainability of such resources due to the growth in population and fragmentation of farm families (Rai, Sharma, and Sundriyal 1994).

Tourism, a fast-growing industry in the state, is putting an additional pressure on resources (Rai and Sundriyal 1997; Maharana, Rai, and Sharma 2000; Chettri, Sharma, Deb, *et al.* 2002). An increased demand of resources for consumptive use of the rural communities and increasing tourism activities in mountains are believed to have a considerable impact on the forest vegetation and wild life (Bjonness 1980; Byers 1986; Singh and Singh 1992; Byers and Banskota 1993; Banskota and Sharma 1994; Chettri, Sharma, Deb 2001; Chettri, Sharma, Deb, *et al.* 2002). Therefore, a careful study of the resource extraction pattern is important for understanding the status of resources and their effective management. This paper

(1) identifies the species preferred as firewood, fodder, and timber, and
(2) delineates the extraction pressure, in terms of annual firewood, fodder, and timber demands in the trekking corridor from Yuksam to Dzongri of the Sikkim Himalaya.

Study area

The Yuksam–Dzongri trekking corridor (26-km-long) starts from an altitude of 1780 m (metre) and goes up to 4000 m above mean sea level. The trail passes through Sachen, Bakhim, and Tshoka in the south-western part of the KBR in Sikkim, India (Figure 1). Yuksam is a trail head for this corridor and leads through Tshoka, Dzongri, and Thangsing to the Khangchendzonga Base Camp and Gocha La in West Sikkim. Yuksam (1780 m) has 11 settlements with 274 households, comprising 1573 individuals. One settlement with eight households resides inside the KBR (Khangchendzonga Biosphere Reserve) at Tshoka (3000 m) along the trail. Other areas, such as Thangsing and Dzongri are not inhabited. A majority of residents are Subbas, followed by Bhutias, Lepchas, and Tibetan refugees. The primary occupation of people is farming while some are also involved in various tourism enterprises such as lodge operators, porters, pack-animal operators, cooks, and trekking guides. Firewood and fodder collection, interior-forest grazing, and leaf litter collection are common practices among these different ethnic groups (Chettri 2000; Maharana, Rai, Chettri, *et al.* 2000; Chettri, Sharma, Deb, *et al.* 2002).

Tourism is increasing at a rapid rate in this area. Annually, about 2000 domestic and foreign tourists visit the area, accompanied by more than 150 support staff (Rai and Sundriyal [1997]; Maharana, Rai, and Sharma [2000]). Apart from these, 140 dzos (a cross between cow and yak) and a dozen horses also operate as pack animals on this trekking trail, on an average six times annually. The HMI (Himalayan Mountaineering Institute) conducts five training programmes for about 500 trainees annually in the area. The trekkers' support staff, including porters hired by travel agents, and HMI trainees collect firewood for cooking and heating along the entire length of the corridor (Chettri, Sharma, Deb, *et al.* 2002). The frequent movement of

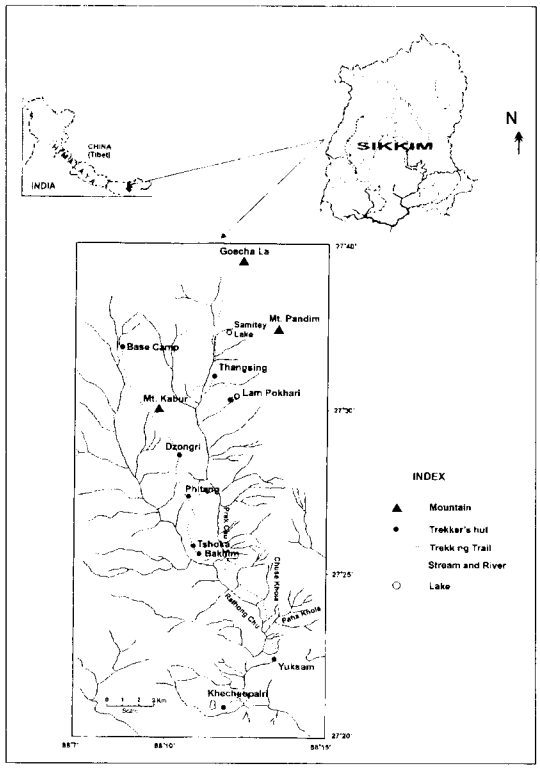

Figure 1 Map showing the Yusam–Dzongri trekking corridor in West Sikkim

pack animals, including herders with additional herds of yaks and sheep owned by the local people, causes an immense pressure on vegetation along the trekking corridor. This has been one of the major factors of habitat destruction and forest fragmentation along the trail.

Methods

In the preliminary phase of the study, the forest-use pattern by communities and their preference for particular species of firewood, fodder, and timber were investigated. Extensive PRA (participatory rural appraisal) tools were used for data collection following Pretty, Guijt, and Thomson (1995). A pair-wise matrix-ranking tool from the PRA was applied for collection of information on preference of

firewood, fodder, and timber species. Preference ranking scores (higher the preference, higher the scores) for fodder, firewood, and timber species were recorded. This information was cross-checked with the other local persons who were not present at the time of the PRA.

The frequency and quantity of resource extraction were monitored from the trailhead of forests. All head loads carried by communities along the trail were recorded. The sex and age of communities carrying loads and forest from where these were collected were also recorded. In case of use of animals as a carrier, the number of animals was recorded and the quantity was estimated with 60 kg/yak and 30 kg/horse as a standard weight as per our observation and estimation. A total of 71 days, spread over all seasons, were randomly sampled for collection during 1997. The frequency of collection was calculated on the basis of the number of persons encountered during sampling. Similarly, extraction pattern of trees on the basis of their diameter was collected from the sample plots set for vegetation analysis (Chettri, Sharma, Deb, *et al.* 2002).

Firewood consumption patterns of different stakeholders were analysed by the weighting method following Fox (1984). Firewood use by different stakeholders was analysed from the survey made from 129 samplings covering thirty-nine households, five hotels/lodges, two groups from the HMI, eight travel agents, and forty-five FTIs (free and independent tourists) (Maharana, Rai, Chettri, *et al.* 2000). They were asked to use the firewood weighed by the researchers for their daily use and re-weighed next day to check how much has been used and how much is left behind. The net used value was taken for analysis. This was repeated for three different seasons. These data were used to estimate the per capita consumption and were then multiplied by the total number of members in a household or the stakeholders to get the daily requirement. The data were standardized on a yearly basis. Fodder demand for the total livestock was calculated by the standardized consumption rate following Sundriyal (1995). Livestock fodder consumption standard rates used were 1.5 kg/day for pig, 15 kg/day for goat, 15 kg/day for sheep, 25 kg/day for horse, 30 kg/day for cattle, 35/kg/day for dzo, and 35 kg/day for yak. Total fodder demand in the area was estimated on the basis of total number of animals and their consumption rates. Likewise, timber utilization patterns were recorded from a semi-structured interview with structured questioners, including estimation of annual or one-time requirements.

Results

Firewood, fodder, and timber: species preference

Baseline information gathered using the PRA tools showed that communities living at Yuksam and Tshoka use a wide variety of plant species for firewood, fodder, and timber (Tables 1 and 2). Due to their knowledge on the virtues of different species and their ability to recognize these species, communities living in these areas collect the preferred species and compensate with the other species if the preferred ones are not available. Results of the preference pair-wise ranking on firewood, fodder, and timber are given in Tables 1 and 2. Eleven woody tree species are listed as widely used firewood from the pair-wise preference ranking at Yuksam. *Quercus lamellose* ranks the highest followed by *Schima wallichii*, *Eurya acuminata*, *Castanopsis hystrix*, *Beilschmiedia sikkimensis*, and *Prunus cerasoides* (Table 1). Likewise, 22 plant species are listed with their preference ranking for fodder from Yuksam. Among these, 59% are trees, 14% shrubs, 18% herbs, and 9% climbers. *Ficus roxburghii* is the highest-ranked species followed by *Pavetta indica*, *Saurauia nepaulensis*, and *Ficus nemoralis* (Table 1).

Table 1 Pair-wise ranking scores of preferred species used as firewood, fodder, and timber at Yuksam, West Sikkim

Species (local name)	*Firewood*	*Fodder*	*Timber*
Acer laevigatum (Putli)	–	4	4
Alnus nepalensis (Uttis)	2	–	1
Amoora wallichii (Laali)	–	5	–
Artemesia vulgaris (Teteypaty)	–	9	–
Arundinella nepalensis (Kharuki)	–	16	–
Beilschmedia sikkimensis (Tarsing)	5	–	2
Betula cylidrostachys (Saur)	–	4	4
Castanopsis hystrix (Patle katus)	4	–	7
Cedrela toona (Tooni)	–	6	7
Cryptomeria japonica (Dhuppi)	2	–	–
Dendrocalamus spp (Bans)	–	1	1
Edgeworthia gardneri (Argeli)	0	–	–
Elatostemma sessile (Gagleto)	–	14	–
Eurya acuminata (Jhinguni)	8	0	–
Ficus nemoralis (Dudhilo)	–	19	–
Ficus roxburghii (Nebara)	–	22	–
Imperata cylindrical (Seeru)	–	10	–
Machilus edulis (Kaulo)	7	3	5
Machilus odoratissima (Lali kaulo)	6	–	5
Juglans regia (Okhar)	–	–	11
Michelia exelsa (Chanp)	–	–	10
Pauzolzia viminea (Chiple)	–	15	–
Paveta indica (Kanyu)	–	21	–
Prunus cerosoides (Panyun)	5	17	–
Prunus nepaulensis (Arupate)	2	–	3
Quercus lamellose (Bajrant)	10	–	9
Rhaphidophora sp (Kanchirna)	–	6	–
Rubia manjith (Majhito)	–	0	–
Saurauia nepaulensis (Gagoon)	–	20	8
Schima wallichi (Chilaune)	9	–	6
Symingtonia populnea (Pipli)	–	2	8
Thysanolaena maxima (Amliso)	–	17	–
Viburnum cordifolia (Asare)	7	3	–
Weigtia gigantia (Bauni kat)	–	2	2

The species preferences are quite different for the Tshoka community as they depend upon the species found in cool temperate and sub-alpine areas (Table 2). *Q. lamellose* ranks higher for firewood followed by *Quercus lineata, Rhododendron arboreum, Betula alnoides, Sorbus* sp., and *Symplocos ramosissima* are among the least-preferred species. *Litsae elongata, Arundanaria* sp., and *Dedrocalamus* sp. have a high ranking as fodder plants. *Acer laevigatum, A. oblongum,* and *Magnolia* sp. are among the least-preferred species. Among timber species, *Michelia exelsa* ranks the highest followed by

Table 2 Pair-wise ranking scores of preferred species used as firewood, fodder, and timber at Tshoka, West Sikkim

Species (local name)	*Firewood*	*Fodder*	*Timber*
Abies densa (Gobre salla)	4	–	11
Acer oblongum (Phirphire)	4	1	8
Acer papilio (Kapase)	3	1	–
Arundanaria sp. (Parang)	6	9	–
Betula alnoides (Saur)	8	3	4
Cyperus sp. (Bukki)	–	7	–
Dendrocalamus sp. (Bans)	1	8	–
Litsae elongata (Pahenli)	2	10	–
Magnolia campbellii (Ghoge chanp)	6	–	4
Magnolia sp. (Phusre chanp)	6	1	–
Prunus rufa (Lekh panyun)	–	4	–
Quercus lamellosa (Bajrant)	10	4	7
Quercus lineata (Phalant)	11	–	8
Rhododendron arboreum (Lali guras)	6	–	–
Rhododendron barbatum (Curling)	6	–	–
Rhododendron falconeri (Curling)	4	–	–
Sorbus sp. (Pansi)	2	–	–
Symplocos ramosissima (Kharane)	1	3	–

Juglans regia and *Q. lamellose* by the Yuksam community and *Abies densa* as the highest followed by Acer oblongum and *Quercus spicata* by the Tshoka community (Tables 1 and 2). *Alnus nepalensis*, although being the least-preferred species, is widely used because of its availability. *Betula alnoides* and *Magnolia campbellii* are among the least-preferred species as other good-quality species by the Tshoka community are widely available.

Firewood, fodder, and timber—collection and utilization

Firewood is collected from forests largely during the winter season due to the availability of manpower. During winter all schools in the study area remain closed. Hence, students free during vacation, join their parents for collection of firewood, increasing the manpower. Moreover, this season is comparatively dry and it is easy for people to move around. The highest frequency of collection was recorded in January and the lowest in September (Figure 2). Data from the field revealed that frequency of trees chopped for use as firewood was the highest for medium-sized trees followed by small and large trees (Figure 3). The total demand for firewood for the community as well as other tourism enterprises was estimated to be 2434 tonnes/year. About 93% of the total demand is used for community needs and only 7% is used for tourism (Table 3). Domestic cooking accounts for about 84% of the total consumption of firewood followed by water heating (11%) and other purposes (5%). Consumption ranges from 2264 tonnes/year by the community to 0.98 tonne/year by pack animal operators. On an average, hotels and lodges consume about 40–50 kg firewood per day. A large quantity of firewood is used by the HMI during training courses for cooking, water heating, and other purposes (Table 3).

There were visible changes in firewood consumption pattern among stakeholders during different seasons (Table 4). A higher firewood

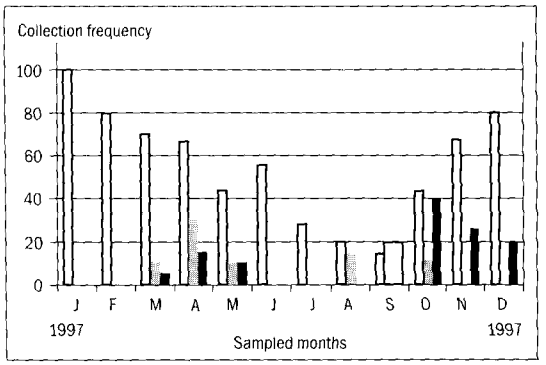

Figure 2 Month-wise firewood collection frequency of community, porter, and tourism agencies along the Yuksam-Dzongri trail. Frequency is expressed in percentage calculated based on collections encountered by authors during field visits

Blank block = frequency of firewood collection by community, grey shaded = frequency of firewood collection by porter, and dark shaded = frequency of firewood collection by tourism agencies

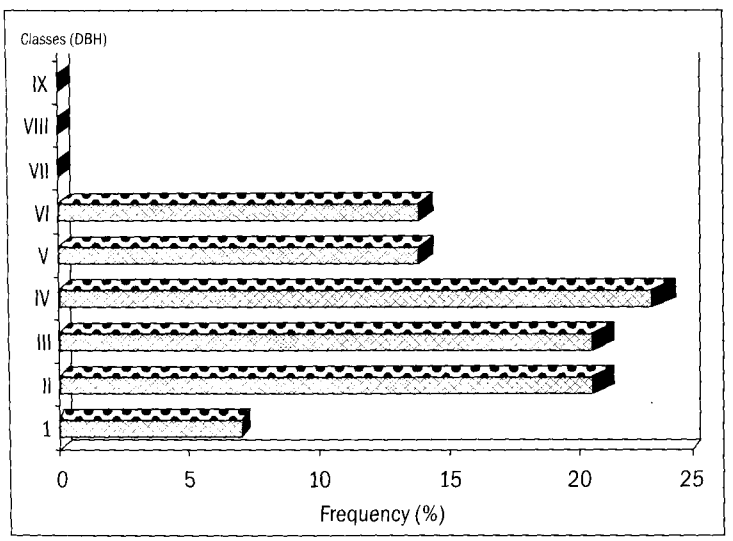

Figure 3 Chopped tree frequency of different diameter at breast height DBH classes showing low pressure (<5%), medium pressure (5%–15%), and high pressure (>15%) on medium-sized (20–50 cm) trees along the Yuksam-Dzongri trail. DBH class (cm) I = 10–20, II = 20–30, III = 30–40, IV = 40–50, V = 50–60, VI = 60–70, VII = 70–80, VIII = 80–90, and IX = 90–100

consumption was recorded during the winter season. The estimated value revealed that the local community alone used three times more firewood in winter as compared to summer (Table 4). The amount of firewood consumption was highest in winter (29 ± 10.1 kg/day/family) and lowest in summer (18 ± 6.9 kg/day/family). Mean daily consumption of firewood was found to be 25.5 kg/day/family for an average household size of 6.28 individuals, with a per capita of 3.45 kg at lower elevation and 4.17 kg at higher elevation.

Table 3 Firewood consumption for different purposes by stakeholders

Stakeholder	*Purposes* (tonnes/year)			
	Cooking	*Water-heating*	*Other purposes*	**Total**
Community	1896	260.0	108.0	2264.0
Hotel/lodges	85	12.0	3.0	100.0
HMI	37	6.0	1.2	44.2
Travel agent	6	1.0	0.2	7.2
FITs	1.4	0.3	0.2	1.9
Pack-animal operator	0.8	0.08	0.1	0.98
Porter	13	0.6	2.0	15.6
Total	2039.2	279.98	114.7	2433.88

HMI - Himalayan Mountaineering Institute; FITs - free and independent trekkers

Table 4 Stakeholder-wise seasonal firewood consumption pattern

Stakeholder (tonnes/year)	*Consumption* (tonnes/year)			*Average*	
	Summer	*Rainy*	*Winter*	(tonnes/year)	*Annual* (tonnes/year)
Community	378.0	757.0	1129.0	6.20[a]	2264.0
Hotel/lodges	17.0	33.0	50.0	0.27[b]	100.0
HMI	2.2	13.0	29.0	0.24[c]	44.2
Travel agent	2.0	1.5	3.7	0.010[d]	7.2
FITs	0.6	00	1.30	0. 001[e]	1.9
Pack-animal operator	0.021	0.34	0.43	0.002[f]	0.98
Porter	2.8	4.25	8.65	0.002[g]	15.6
Total	402.62	809.09	1220.08	6.725	2433.88

[a, b] Community and hotel consumption per day; [c, d] per group; [e, f, g] per person

HMI - Himalayan Mountaineering Institute; FITs - free and independent trekkers

Four sources of firewood supply areas were identified from the questioners, viz.
(1) homestead surroundings, (2) privately owned wooded (agroforestry) area,
(3) community-used forest (khasmal), and
(4) reserve forest and biosphere reserve. Both, privately owned forest and government forests meet most demands of firewood (Figure 4). About 78% of firewood comes from government forests, including the biosphere reserve, and only 19% comes as support from private forests. Homestead surroundings provide *Jhikra* (3%) that includes portions of old wooded fences, dried bamboo pieces as it ignites fast, and agricultural residues, such as maize and millet stacks, especially for livestock feed preparation. From the household surveys it was revealed that about 79% of the total households depend upon firewood for cooking and other purposes, followed by 14% of the households on kerosene oil, 4% on electricity, and 3% on LPG (liquefied petroleum gas).

On the basis of standard values for livestock, total demand of fodder was estimated at 1209 tonnes/year for the entire livestock present in the study area (Table 5). During 1996–98, a net increase of 63% fodder demand was estimated. Fodder demand for cattle was the highest (41%),

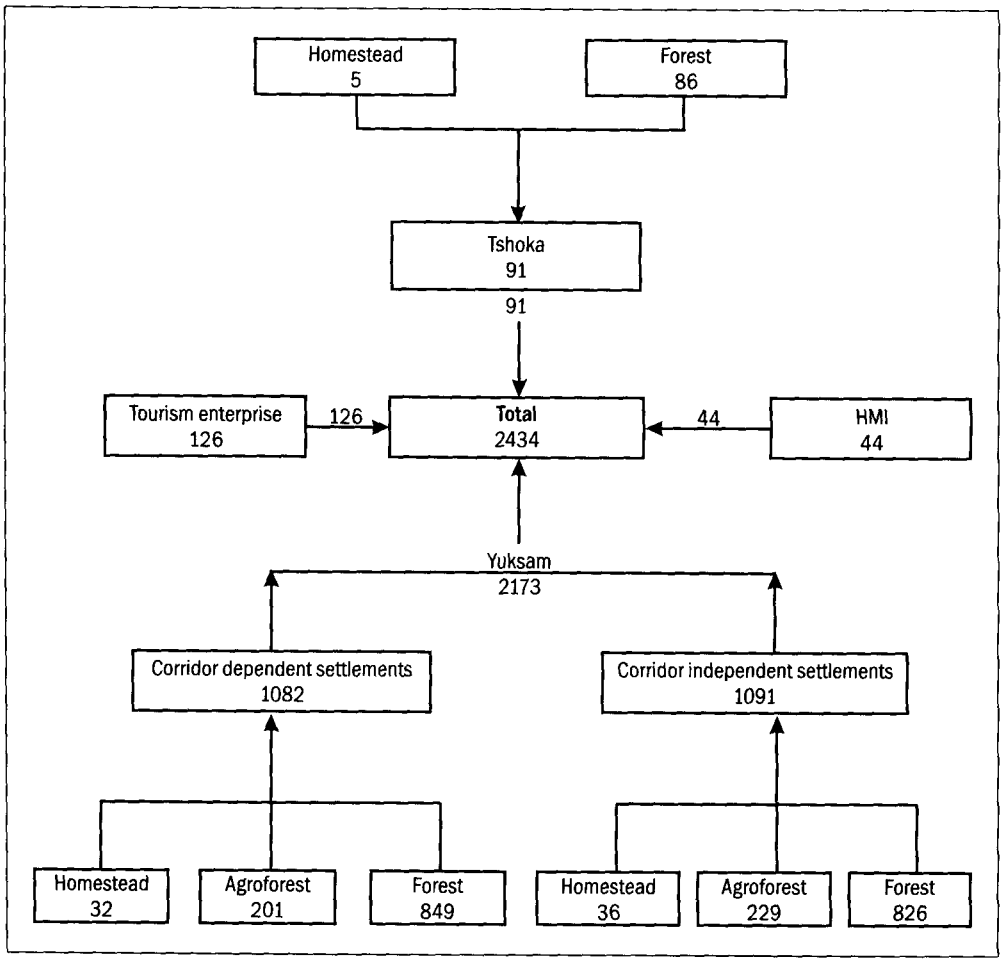

Figure 4 Annual firewood consumption (tonnes) from different land-use sources for Yuksam and Tshoka settlements and non-community use (tourism and Himalayan Mountaineering Institute courses) along the Yuksam-Dzongri forest corridor

followed by sheep (21%), and goat (14%). Demands for dzo, yak, pig, and horse were 13%, 8%, 1%, and 2%, respectively, of the total.

A large number of trees with <10 cm DBH (diameter at breast height) were used as timber for constructing and renovating houses in just a period of 3–5 years (Table 6). However, it is the small-sized poles that are used in a higher number as timber. This is mainly due to the use of small timbers in fencing and cow sheds, which need frequent replacements. Use of medium-sized trees (20–40 cm DBH) and large trees (30–70 cm DBH) was comparatively low and these were used in a larger period of 5–7 years and 15–25 years, respectively as these are needed only for major renovations, which take place once a while.

Discussion

In the study area, a wide variety of plant species are used based upon their being preferred for firewood, fodder, or timber. Dependency on forest for firewood is seen to be higher than in similar types of studies made by Sharma,

Table 5 Livestock number, increase during 1996-98, and fodder consumption estimation from Yuksam and Yuksam-Dzongri trekking corridor

Livestock	Years 1996	1998	Fodder consumption (tonnes/year)	Increase in fodder consumption %
Dzo	96	122	156	27
Yak	83	78	100	–6
Horse	31	22	20	–29
Cattle	245	454	497	85
Goat	361	311	170	–14
Sheep	441	461	252	5
Pig	273	260	14	–5
Total	1530	1708	1209	63

Table 6 Timber use pattern for private construction by community of Yuksam and Tshoka

Characteristics	Dimensions
Large-size poles	
Time interval (years)	15-25
Tree number	2-5
Average (DBH) size (cm)	40-70
Wood volume required (m^3)	2.35-4.77
Medium-size poles	
Time interval (years)	5-7
Tree number	10-15
Average size (DBH) size (cm)	20-40
Wood volume required (m^3)	2.16-7.1
Small-size poles (mainly bamboo)	
Time intervals (years)	3-5
Number of poles required	80-120
Average (DBH) size (cm)	<10
Wood volume required (m^3)	8.16-15.1

DBH – diameter at breast height

Sundriyal, Rai, *et al.* (1992) in other parts of Sikkim. Forests in the study area are under tremendous pressure for firewood, fodder, and timber as settlements are located in the vicinity of KBR and the tourism sector is growing in an uncontrolled manner.

The preference of resources by local communities is an age-old trend in the Himalayas but scientific studies of the same are few (Purohit and Nautiyal 1986; Purohit and Sammant 1995; Rai, Chettri, and Sharma 2002). These studies reveal that ideal firewood qualities are high calorie of heat during combustion, high density of wood, low ash content, and low moisture content as reported by Rai, Chettri, and Sharma (2002). The preference and usage pattern of different species depends upon the quality of firewood, season of collection, and time required for drying it before use. The people of Yuksam depend upon the natural forest for certain species of their choice for firewood, fodder, and timber. Extraction of high-quality species for firewood, fodder, and timber has resulted in a decline in the number of such trees along the corridor. On the other hand, the Tshoka community is completely dependant on resources of KBR for all forest-based resource requirements.

The annual demand of firewood, fodder, and timber is much more than any in other studies in the state made by Sundriyal, Sharma, Rai, *et al.* (1994) and Sundriyal and Sharma (1996). Local conservation initiatives and interventions from an ecotourism project have had a visible impact on firewood use by the community and on tourism enterprises. Although alarming, the rate of woody biomass extraction was nonetheless lower than the annual productivity rate in the study area (Chettri, Sharma, Deb, *et al.* 2002). Firewood collection and stocking for the rainy season by villagers have been a common practice in the area. Firewood is collected either from felled trees or from chopped branches. Firewood and fodder are collected in head-loads, either by putting these into a doko (bamboo basket) or by tying the load with a rope or bark of Argeli (*Edgeworthia gardeneri*). Men, women, children, and even dzos and horses are engaged in carrying firewood loads from the forest to villages. The pressure on natural resources on the trail forest is comparatively higher than in the surrounding forests. Pressure from

tourism, in terms of firewood use, is also significant. Such pressure at a high altitude area might result in severe degradation in future, bringing about a considerable impact on forests and wildlife (Bjonness [1980]; Byers [1986]; Banskota and Sharma [1994]; Chettri, Sharma, and Deb [2001], Chettri, Sharma, Deb, *et al.* [2002]).

A remarkable increase in the number of cattle and dzo was seen during 1996 and 1998 in the study area. This was mainly due to promotion of tourism where the use of milk and its products increased tremendously during this period. The increase in the number of *dzo* is also directly related to tourism as more pack animals are in demand due to an increase in tourism. Interestingly, the economy of keeping dzo is found more beneficial than cattle or yak since it fetches more money from dzo than other economic options from these animals (Tambe 2000). An increase in pack animals and fodder demand are the real concern for conservation along the trekking trail (Chettri 2000).

Field observations revealed that forests remained undisturbed at steeper slopes. Forest degradation showed an increase in forests where human interference was more pronounced. This indicates that resources were generally used from forests situated in gentle slopes. This could mainly be due to the easy access to these sites as reported in the study by Brown, Gillerpie, and Lugo (1991). Chopping of trees and lopping off branches whose numbers were higher in the disturbed areas, have significantly disrupted the canopy structure, leading to open conditions (Chettri, Sharma, Deb, *et al.* 2002).

Conclusion

Forest-based resources are an integral part of people's livelihood in the study area. The local community depends upon forests for firewood, fodder, timber, and many other non-timber forest products. Extraction of firewood, fodder, and timber for community and tourism purposes is observed all along the trekking corridor. Pressure is more pronounced near major settlements of Yuksam. Tourism-related pressure on the forest is distinctly noticeable at Tshoka, the first camping site along the trail. Good-quality species are declining at an alarming rate and the area is dominated by secondary species. The forest species composition and structure are changing rapidly due to selective removal of preferred species. Thus, the Yuksam-Dzongri trekking corridor of KBR in Sikkim is facing an immense human pressure on its natural resources. This is mainly due to the rapid increase in tourist numbers and livestock.

Disturbances are pronounced in forests near settlements and campsites due to an immense human as well as grazing pressure. Management and regulation of tourism is weak and inadequate. Management of the trekking-corridor forests should be oriented in a way that pressure on the preferred canopy species is minimized. Natural regeneration should be promoted in the area and simultaneously, the persistent continued pressure on forest resources should be discouraged. Entrepreneurs and the community should be made aware of the legal status of KBR. Use of alternative sources of energy should be encouraged for improvement of forest conditions to make the area more attractive and valuable, in terms of biodiversity. During 1996–2000, participatory management of natural resources and compliance with the code of conduct for conservation by tourists, enterprises, and communities, especially on the use of alternatives to firewood, were promoted through the Sikkim Biodiversity and Ecotourism Project. However, these activities should be followed with a strict regulatory mechanism and restoration process to conserve this fragile and biodiversity-rich area.

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References

Bajracharya D. 1983
Fuel, food or forest? Dilemmas in a Nepali village
World Development **11:** 1057–1074

Banskota K and Sharma B. 1994
Tourism for mountain community development: case study report on the Annapurna and Ghorkha regions of Nepal [Discussion Paper Series No. MEI 95/11]
Kathmandu: Centre for Resource and Environmental Studies and International Centre for Integrated Mountain Development. 233 pp.

Bjonness I. 1980
Animal husbandry and grazing, a conservation and management problem in Sagarmatha (Mt Everest) National Park (SNP), Nepal
Norsk Geografisk Tidsskrift **34**: 59–76

Blaikie P. 1985
The Political Economy of Soil Erosion in Developing Countries
New York: Longman. 311 pp.

Brown S, Gillerpie A J R, and Lugo A E. 1991
Biomass of tropical forest of South and Southeast Asia
Canadian Journal of Forest Research **21**: 111–117

Brown S and Lugo A E. 1982
The shortage of production of organic matter in tropical forest and their role in the global carbon cycle
Biotropica **14**: 161–187

Byers A C. 1986
An assessment of landscape change in the Khumbu region of Nepal using repeat photography
Mountain Research and Development 7: 77–81

Byers A C and Banskota K. 1993
Environmental impacts of back century tourism on three sides of Everest
World Heritage twenty years later
Switzerland and UK: World Conservation Union IUCN (GLAND) and Cambridge University Press

Chettri N. 2000
Impact of habitat disturbances on bird and butterfly communities along the Yuksam–Dzongri trail in Khangchendzonga Biosphere Reserve. pp. 266
[PhD thesis submitted to Department of Zoology, University of North Bengal, Sivmandir, West Bengal, India]

Chettri N, Sharma E, and Deb D C. 2001
Bird community structure along a trekking corridor of Sikkim Himalaya: a conservation perspective
Biological Conservation **102**(1): 1–16

Chettri N, Sharma E, Deb D C, Sundriyal R C. 2002
Effect of firewood extraction on tree structure, regeneration, and woody biomass productivity in a trekking corridor of the Sikkim Himalaya
Mountain Research and Development **22**(2): 150–158

Eckholm E P, Foley G, Banard G, Timberlake L. 1984
Firewood: The Energy Crisis that Won't Go Away
London: International Institute for Environment and Development. 107 pp.

FAO (Food and Agricultural Organization). 1994
Forest Development and Policy Dilemmas
Rome: FAO

Fox J. 1984
Firewood consumption in a Nepali village
Environmental Management **8**: 243–250

Government of Sikkim, RRSSC (Regional Remote Sensing Service Centre), and ISRO (Indian Space Research Organization). 1994
Forest Cover Mapping through Digital Image Processing of India Remote Sensing Satellite Data with Special Reference to Sikkim: procedural manual and inventory
Department of Forest, Government of Sikkim, RRSSC, and ISRO, Government of India, 590 pp.

Hannah L, Carr J L, and Lakerani A. 1995
Human disturbances and natural habitat: A biome level analysis of a global dataset
Biodiversity and Conservation **4**: 128–155

Maharana I, Rai S C, and Sharma E. 2000
Environmental economics of Khangchendzonga National Park in the Sikkim Himalaya, India
GeoJournal **50**: 329–337

Maharana I, Rai S C, Chettri N, Sharma E. 2000
Firewood pressure on the natural forests of Khangchendzonga National Park of Sikkim Himalaya
In *Sustainable Management of Forest—India*, edited by A Arunachalam and M L Khan. 560 pp.
Dehra Dun: International Book Distributors, pp. 279–295

Mahat T B S, Griffin D M, and Sheperd K R. 1987
Human impact of some forest of middle hills of Nepal (part 4). A detail study in southeast Sindhu Palchok and northeast Kabre Palanchok
Mountain Research and Development 7: 111–134

Pretty J N, Guijt I, and Thomson J. 1995
A Trainers Guide to Participatory Learning and Action
London: IIED (International Institute for Environment and Development) Series

Purohit A N and Nautiyal A R. 1986
Firewood value index of Indian mountain tree species
The International Tree Crops Journal **4**: 177–182

Purohit K and Sammant S S. 1995
Fodder Trees and Shrubs of Central Himalaya
Nainital: Gyanodaya Prakashan. 116 pp.

Rai S C and Sundriyal R C. 1997
Tourism development and biodiversity conservation: A case study from the Sikkim Himalaya
Ambio **26**: 235–242

Rai S C, Sharma E, and Sundriyal R C. 1994
Conservation in the Sikkim Himalaya: traditional knowledge and land use of the Mamlay watershed
Environmental Conservation **15**: 30–35

Rai Y K, Chettri N, and Sharma E. 2002
Fuelwood value index of woody tree species from forests of Mamlay Watershed, South Sikkim, India
Forests, Trees and Livelihoods **12**: 209–219

Sharma E, Sundriyal R C, Rai S C, Bhatt Y K, Rai L K, Sharma R, Rai Y K. 1992
Integrated Watershed Management: A Case Study in Sikkim Himalaya
Nainital: Gyanodaya Prakashan. 120 pp.

Singh J S and Singh S P. 1992
Forest of Himalaya: structure, function, and impact of man
Nainital: Gyanodaya Prakashan

Sundriyal R C. 1995
Grassland forage production and management in the Himalaya: A review
Journal of Hill Research **8**: 135–150

Sundriyal R C and Sharma E. 1996
Anthropogenic pressure on tree structure and biomass in the temperate forest on Mamlay Watershed in Sikkim
Forest Ecology and Management **81**: 113–134

Sundriyal R C, Sharma E, Rai L K, Rai S C. 1994
Tree structure, regeneration and woody biomass removal in a sub-tropical forest of Mamlay Watershed in the Sikkim Himalaya
Vegetatio **113**: 53–63

Tambe S. 2000
Community Based Grazing Area Management Plan for the Dzongri Alpine Meadows
[unpublished project report]
Dehra Dun: Indira Gandhi National Forest Academy

Thapa G B and Weber K E. 1990
Actors and factors of deforestation in Tropical Asia
Environmental Conservation **17**: 19–27

WRI (World Resources Institute) and IIED (International Institute for Environment and Development). 1987
World Resources 1987
New York: Basic Books, Inc. for the WRI. pp. 375