Impact of Firewood Extraction on Tree Structure, Regeneration and Woody Biomass Productivity in a Trekking Corridor of the Sikkim Himalaya

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Source: Mountain Research and Development, 22(2) : 150-158

Published By: International Mountain Society

URL: https://doi.org/10.1659/0276-4741(2002)022[0150:IOFEOT]2.0.CO;2

Mountain Research and Development Vol 22 No 2 May 2002: 150–158

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Forest cover types, tree distribution pattern, species diversity, net woody biomass productivity, and firewood extraction rates were studied along a trekking corridor (Yuksam–Dzongri) in Khangchendzonga Biosphere Reserve, Sikkim, India. For the last 2 decades the area has been facing immense pressure on its natural resources because of an increase in the numbers of tourists and the lack of effective regulation by park authorities. To assess this situation the study sites were categorized as closed canopy (CC) forest and open canopy (OC) forest (disturbed) at upper forest (UF) and lower forest (LF) sites, on the basis of firewood extraction pressure from the community and tourism enterprises. The results showed significant variations in diversity, richness, structure, productivity, and regeneration among different canopy types. OC forest showed greater plant diversity than CC forest. Firewood extraction pressure was remarkably greater in the LF near the major settlement than in the UF. Local conservation initiatives and the interventions of an ecotourism project have had visible impacts 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 of the stands. Participatory management and compliance by tourism enterprises with a code of conduct on alternative fuel use along the trekking corridor would help promote the conservation and maintenance of biodiversity.

Keywords: *Forest cover; species diversity; temperate forest; subalpine forest; regeneration; productivity; firewood extraction; India.*

Peer reviewed: *December 2001.* ***Accepted:*** *January 2002.*

Introduction

Firewood is the only source of energy for many people living in the mountains (Fox 1984; Mahat et al 1987; Sundriyal and Sharma 1996) because it is freely and easily accessible and simple to use (Eckholm et al 1984; Blaikie 1985). Other forms of commercial energy are beyond the reach of ordinary people because of poor socioeconomic conditions, lack of communication, high prices, and limited supply in inaccessible mountain areas. Extensive use of firewood by communities and the tourist sector has been exerting pressure on the forests, causing continuous loss of biomass. This poses threats to the biological resources in the region (Byers 1986; Banskota and Sharma 1994; Rai and Sundriyal 1997; Rai and Sharma 1998). Firewood extraction has been one of the major factors responsible for the destruction of forests in the Himalaya.

In Sikkim, 43% of the land area is under forest cover, 34% of which is categorized as dense (Department of Forests 1994). Most people in Sikkim depend on forests for firewood, substantial portions of which come from agroforestry systems (Sharma et al 1992). Tourism in Sikkim is a rapidly growing industry, which has seen a roughly 10-fold increase in visitors during the past 2 decades. This has resulted in encroachment on the forests for firewood (Rai and Sundriyal 1997; Chettri 2000). Government regulations in Sikkim forbid the use of firewood at tourist destinations. However, because of lack of regulations and enforcement, trekking support staff and some travel agents continue to use firewood in remote trekking areas. The Yuksam–Dzongri trekking corridor in Sikkim is an excellent site for studies on the impact of firewood use on forests. If forest degradation and destruction along this trekking corridor continue, they are likely to have impacts on both the appearance and the ecological balance of the site.

These negative impacts on the forests are bound to affect tourist arrivals and, consequently, the local economy. There is a need to understand the impacts of firewood extraction on forest quality in terms of maintenance and management, as well as the impacts on the sustainability of tourism. The present study was therefore carried out to examine firewood use by communities and tourism enterprises and its impacts on forest structure, tree species regeneration, and woody biomass productivity in a trekking corridor in western Sikkim. Because many new areas are being opened to tourism in the Himalayan region, the findings of this study could provide valuable information for the management of similar sites in the Hindu-Kush Himalayan region and other mountain regions of the world.

Study area: The Yuksam–Dzongri trekking corridor

Yuksam (1780 m) was the first capital of Sikkim. It has 11 settlements with 274 households and a population of 1753. It is a trailhead for Dzongri, Thangsing, and Goche La, and a base camp for Khangchendzonga (the third highest mountain in the world) in western Sikkim (Figure 1). The tourist trekking corridor extends over a distance of 26 km from Yuksam to Dzongri, at elevations ranging from 1780 to 4000 m. One settlement with 8 households is located on the trail at Tshoka (3000 m). Some portions of the trekking corridor at the higher altitudes were declared a part of Khangchendzonga National Park in 1986. In 2000 the national park was

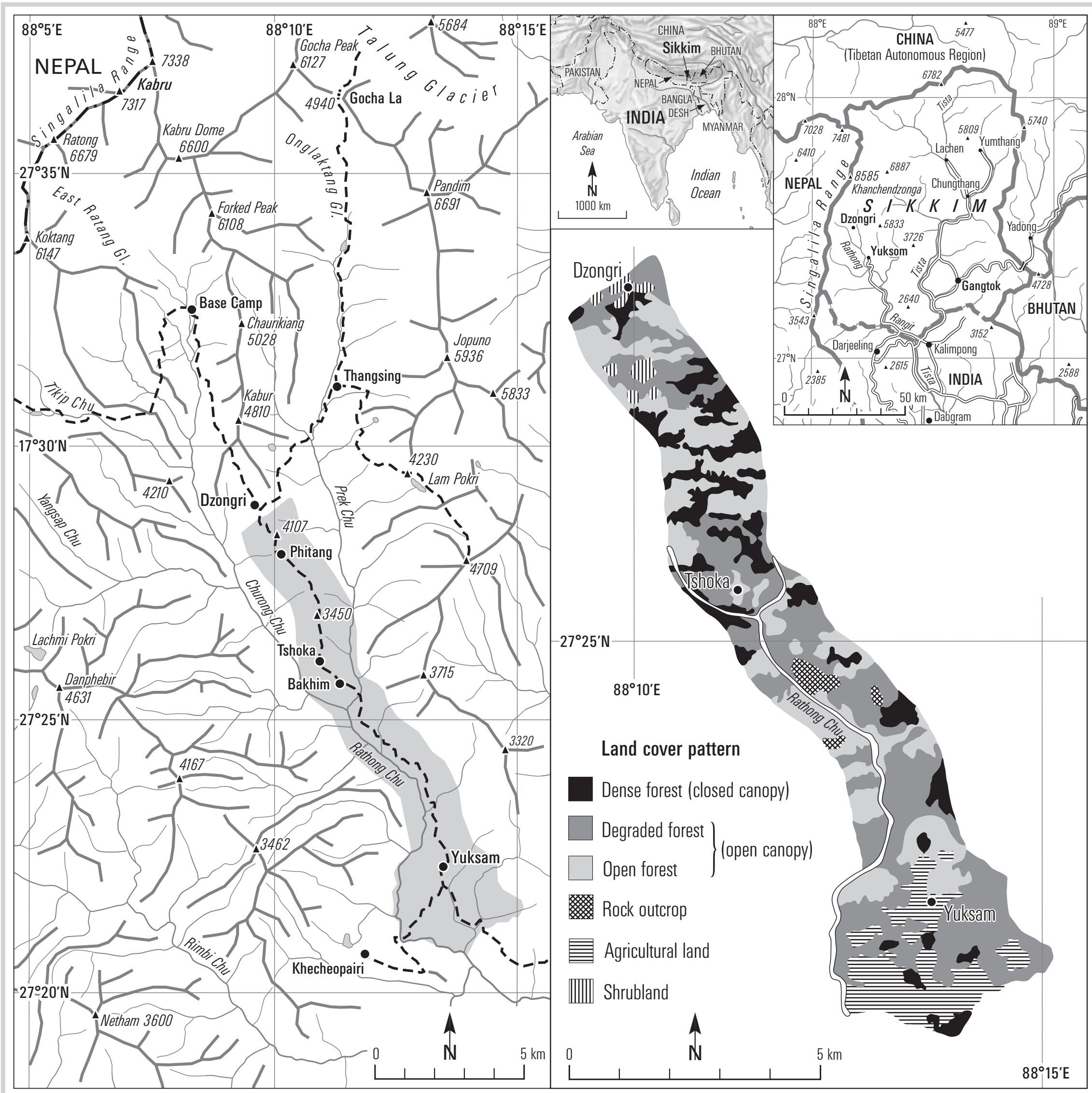


FIGURE 1 Location map showing the Yuksam–Dzongri trekking corridor in the Khangchendzonga Biosphere Reserve in Sikkim, India. (Map by authors and Andreas Brodbeck)

expanded and designated as the Khangchendzonga Biosphere Reserve, and the entire Yuksam–Dzongri trekking corridor was included in it. The Wildlife Division of the Department of Forests is the sole authority responsible for management and protection of the reserve; it is responsible for maintenance of the trekking corridor in collaboration with the Department of Tourism. Along this trekking corridor there are camping sites at Yuksam, Sachen, Bakhim, Tshoka, and Dzongri. There are trekkers' huts at Dzongri, Tshoka, and Yuksam, lodges at Tshoka and Yuksam, and Department of Forests guest houses at Bakhim and Yuksam. The number of Wildlife Division personnel posted in the area is small in relation to their task of monitoring the harvesting and use of firewood in the entire corridor.

The Subbas are the main ethnic group in Yuksam, followed by Bhotiyas, Lepchas, Nepalese, and Tibetan refugees. The primary occupation of these communities is farming, although some are associated with tourism as lodge operators, porters, yakmen, cooks, and naturalist guides for trekkers. About 50% of the population depends on the forest in the trekking corridor for natural resources such as firewood, timber, and fodder. Himalayan Mountaineering Institute (HMI) trainees and trekking tour staff, including porters, have been using firewood for cooking and heating all along the corridor. This has put tremendous pressure on forests in the corridor, resulting in visible empty spots and thinning of trees.

Methods

Land use areas were estimated using Survey of India topo-sheets (1:50,000) and Indian Remote Sensing 1A Linear Imaging Self Scanning II (IRS-IA LISS II) satellite data for 1988. Calculation of the total area of the trekking corridor included an area of 1 km on each side of the trail from Yuksam (1780 m) to Dzongri (4000 m)

TABLE 1 Seasonal firewood consumption patterns by different stakeholders in Yuksam and on the Yuksam–Dzongri trekking trail.

Stakeholders	Consumption (tons)				
	Summer	Monsoon	Winter	Average (tons)	Annual (tons)
Community	378.32	756.64	1128.76	6.20[a]	2264
Hotels/lodges	16.72	33.45	49.90	0.27[b]	100
Himalayan Mountaineering Institute	2.30	13.07	28.51	0.24[c]	44
Travel agents	0.16	3.40	3.56	0.010[c]	7.2
Individual tourists	0.65	0.00	1.30	0.001[d]	1.9
Pack animal operators	0.086	0.41	0.53	0.002[d]	0.98
Porters	0.28	6.50	8.85	0.002[d]	15.6

[a]Community consumption per day.
[b]Hotel consumption per day.
[c]Consumption per group per day.
[d]Consumption per person per day.

with an approximate distance of 26 km. Depending on forest utilization by the settlements, the trekking corridor forest was divided into temperate broadleaf forest (1780–2350 m), designated as lower forest (LF), and temperate subalpine forest (2350–3600 m), designated as upper forest (UF). The communities of Yuksam and Tshoka use these forests to meet their subsistence needs. HMI courses and tourism enterprises also use the resources of the area while offering both training and recreation. Annual firewood demand and seasonal-use patterns were estimated by weighing the wood at each of the stratified sampling households in 3 separate seasons, namely summer, monsoon, and winter, according to Fox (1984). These data were used to estimate the per capita consumption and then multiplied by the total members in a household to obtain the daily requirement.

Woody tree species composition and distribution patterns were sampled at 2 different sites in the LF and the UF, depending on the percentage of canopy cover. Closed canopy (CC) forests were dense, whereas open canopy (OC) forests were degraded. Forests with canopy coverage of <40% were treated as OC forests, where firewood extraction pressure was observed to be at a maximum, and those with >40% canopy coverage were treated as CC forests, where the pressure was relatively low. One hundred 10 × 10-m vegetation sampling plots (25 each in OC and CC forests in the LF and the UF) were chosen randomly along the corridor. Tree species (>10-cm diameter at 1.3-m height above the ground) in each sampling plot were identified, recorded, and used for importance value index (IVI) calculation according to Sundriyal and Sharma (1996). Saplings (>2.5-cm diameter) and seedlings (<2.5-cm diameter) were recorded in 5 × 5-m subplots numbering 5 in each stand. Shannon–Wiener's index of species diversity and concentration of dominance were estimated according to Hayek and Buzas (1997).

Nineteen 30 × 40-m plots (OC = 5, CC = 4 in the LF, and OC = 6, CC = 4 in the UF) were set in January 1997 in the LF and in May 1997 in the UF. Trees within each plot were identified, marked, and measured 1.3 m above the ground for annual increment of diameter at breast height (dbh). The dbh was measured again in January and May 1998. Biomass of trees was calculated using the allometric relationship developed by Sundriyal et al (1994) and Sundriyal and Sharma (1996). Woody biomass removal was estimated on 10 random 20 × 20-m plots from each representative stand. Girth at the base of each stump was measured and converted to dbh. The tree height class was derived by matching its calculated dbh to the mean height of similar-sized trees, as measured on the permanent plots, and the biomass was estimated. These data were compared with the estimates of firewood extraction and consumption recorded in systematic household interviews. Because some of the trees were removed from the marked plots, net primary productivity (NPP) was calculated taking the standing and removed biomass into account. However, for net ecosystem productivity (NEP), removed biomass was subtracted and only the productivity of standing trees was calculated (Sundriyal and Sharma 1996).

Results

Forest cover types

The designated study area consisted of 3709 ha with 54% OC forests (degraded and open forest), 18% CC forests (dense forest), and 5% shrubland (Figure 1). Agriculture was the predominant nonforest land use, occupying 14% of the area. About 3% was classified as wasteland (rock outcrop and landslide), 2% as built-up land, and 4% as surface water. Forest covered 72% of the total area.

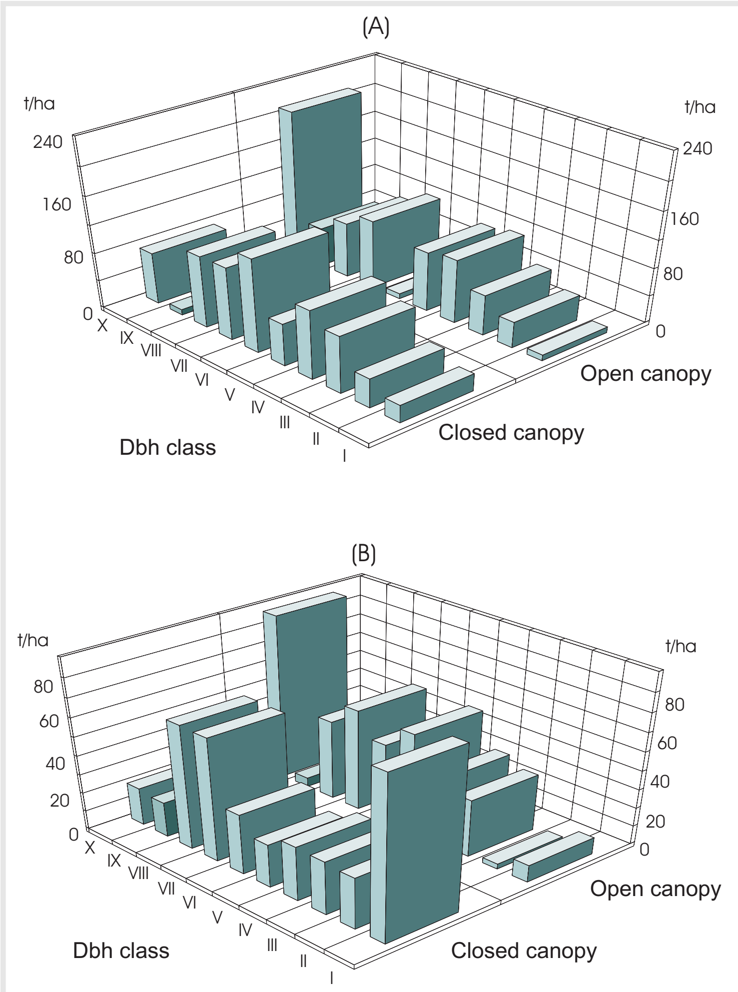
TABLE 2 Existing woody biomass, net primary productivity, extraction, and net ecosystem productivity in the lower and upper forest along the Yuksam–Dzongri trekking corridor. CC, closed canopy forest; OC, open canopy forest; LF, lower forest; UF, upper forest.

Site, with CC or OC and species	Standing biomass (tons/ha)	Net primary productivity (tons/ha/y)	Extraction (tons/ha/y)	Net ecosystem productivity (tons/ha/y)
LF/CC				
Quercus lamellosa	261.68	2.01	1.12	0.89
Beilschmedia sikkimensis	78.44	1.88	0.72	1.16
Machilus edulis	36.37	0.45	—	0.45
Machilus odoratissima	34.99	0.80	—	0.80
Acer laevigatum	24.47	0.90	0.54	0.36
Others (25)	267.84	5.31	2.38	2.93
Total	703.79	11.35	4.76	6.59
LF/OC				
Q. lamellosa	158.97	4.57	2.28	2.29
***Quercus* spp**	33.88	1.58	1.12	0.46
Castanopsis hystrix	33.50	0.25	—	0.25
Nyssa javanica	22.44	0.08	—	0.08
Garuga gamblei	9.54	1.12	—	1.12
Others (38)	140.83	8.66	4.36	4.30
Total	399.16	16.26	7.76	8.50
UF/CC				
Abies densa	126.09	8.36	—	8.36
Acer papilio	75.64	1.07	0.53	0.54
***Quercus* spp**	47.82	1.15	0.87	0.28
Magnolia campbellii	22.63	0.30	—	0.30
Litsae elongata	11.74	0.16	—	0.16
Others (18)	98.50	2.45	1.4	1.06
Total	382.42	13.50	2.8	10.70
UF/OC				
A. densa	95.46	0.40	—	0.40
M. campbellii	53.13	1.06	0.63	0.43
Unknown (*Arare kanda*)	32.31	0.16	—	0.16
***Quercus* spp**	24.60	0.06	—	0.06
Betula alnoides	16.82	0.74	0.62	0.12
Others (19)	84.04	8.91	3.93	4.98
Total	306.36	11.33	5.18	6.15

Annual firewood consumption, productivity, and extraction

The total demand for firewood for community and tourism enterprises was estimated at 2433 tons/y (Table 1). About 55% of the total demand for community and commercial uses (tourism) was met by forests along the trail, which were thus under considerable pressure. Consumption for domestic cooking and other purposes ranged between 2264 tons/y for communities to a low value of 1.02 tons/y for pack animal operators. Pressure from hotels, lodges, and the HMI was also quite conspicuous. Changes in the firewood consump-

FIGURE 2 Distribution of woody biomass (tons/ha) per dbh class in CC and OC forests in the LF (A) and the UF (B) along the Yuksam–Dzongri trail. Dbh classes (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, IX = 90–100, and X > 100.



tion pattern were distinct among the stakeholders, resulting from altitudinal and climatic variations in locations along the trail (Table 1). Firewood consumption by all stakeholders was highest during the winter season. Estimated values revealed that communities alone used 3 times more firewood in winter than in summer (Table 1).

Existing woody biomass, net primary woody biomass productivity, extraction, and NEP are presented in Table 2. *Quercus lamellosa* accounted for 37–40% of the existing woody biomass and 18–28% NPP of the stands in both CC and OC forests in the LF. Existing woody biomass was greater in the CC than in the OC in both the LF and the UF. But the NPP of woody biomass in the LF was greater (16.26 tons/ha/y) in the OC than in the CC forest (11.35 tons/ha/y) as a result of the faster growth after canopy opening. The NPP of the UF showed a contrasting result, with a higher (13.5 tons/ha/y) value in the CC than in the OC (11.3 tons/ha/y). Extraction of nearly 50% of the NPP was recorded for the CC and the OC in the LF, and 46% from the OC and 21% from the CC in the UF. This indicated greater pressure on forests at lower altitudes and near settlements. Extraction of *Q. lamellosa* was highest in both the CC and the OC forests, followed by *Beilschmedia sikkimensis*, *Acer laevigatum*, and *Quercus* spp, because of their greater desirability as fuel (Table 2). Distributions of woody biomass in different dbh classes were found to have uneven patterns resulting from selective harvest of medium-dbh-class trees by communities (Figure 2). Users preferred medium-size trees for convenience in extraction, transportation, and usage.

Stand structure and regeneration

Species diversity, richness, and concentration are presented in Table 3. In the LF, tree species diversity was greater in the OC (H' = 5.5) than in the CC (H' = 2.04), whereas in the UF, diversity was greater in the CC (H' = 2.8) than in the OC (H' = 2.5). In the UF, the pressure on forests was much lower, but secondary species had only a limited chance because of climatic constraints. Secondary species in OC forests played a major role in bringing about changes in species richness, concentration, and basal area (Table 3).

TABLE 3 Species diversity, stand dimensions, and regeneration in the LF and the UF along the Yuksam–Dzongri trail. CC, closed canopy forest; OC, open canopy forest; LF, lower forest; UF, upper forest.

	Lower forest		Upper forest	
Diversity indices	**CC**	**OC**	**CC**	**OC**
Shannon–Weiner's diversity index (H')	2.04	5.52	2.8	2.5
Margalef's species richness (d)	5.4	8.8	4.2	4.7
Basal area (m^2/ha)	59	23	50	40
Density (trees per hectare)	435	206	319	222
Tree species (number per site)	30	43	23	24
Regenerating species (number per site)	13	13	13	14
Regeneration (seedlings per hectare)	3480	2642	3694	2100
Regeneration (saplings per hectare)	1360	1200	860	585

TABLE 4 Regeneration status (individuals per hectare) of some widespread tree species in the Yuksam–Dzongri trekking corridor. Values refer to the number of seedlings, with the number of saplings in parentheses. CC, closed canopy forest; OC, open canopy forest.

	Lower forest		Upper forest	
Species	**CC**	**OC**	**CC**	**OC**
Eurya acuminata	840 (440)	480 (176)	80 (60)	373 (80)
Symplocos ramiosissima	460 (240)	352 (272)		
Cinnamomum cecidodaphnae	420 (40)			
Quercus lineata	380 (80)		120 (40)	
Neonaucleo griffithi	320 (180)	272 (64)		
Viburnum cordifolia	260 (100)	464 (128)		
Castanopsis tribuloides	240 (80)	48 (0)		
Machilus edulis	180 (60)	224 (112)		227 (40)
Beilschmedia sikkimensis	100 (40)			
Acer oblongum	80 (40)			
Quercus spicata	80 (20)			27 (0)
Betula cylindrostachys	80 (20)			
Quercus lamellosa	40 (20)	96 (80)		
Engelhardtia spicata		320 (16)		
Castanopsis hystrix		224 (144)		
Sterculia villosa		130 (0)		
Alnus nepalensis		80 (48)		
Mahonia sikkimensis		80 (48)		200 (40)
Prunus nepalensis		80 (32)		133 (53)
Andromeda elliptica		16 (80)	60 (20)	
Rhododendron falconeri			880 (180)	67 (26)
Rhododendron grande			520 (60)	40 (40)
Rhododendron arboreum			520 (180)	253 (67)
Magnolia campbellii			400 (40)	400 (80)
Rhododendron barbatum			380 (40)	147 (80)
Litsae elongata			280 (60)	
Acer thompsoni			240 (60)	0 (13)
Sorbus spp			120 (40)	
Betula alnoides			67 (40)	140 (13)
Abies densa			27 (40)	80 (13)
Acer laevigatum				53 (13)
Quercus spp				67 (27)

Only 43% of the total of 56 species in the LF were found to be regenerating in the CC and 47% in the OC. Similarly, out of 32 species, 56% of the total in the CC and 58% in the OC were found to be regenerating in the UF (Table 4). Secondary species such as *Symplocos ramosissima* and *Eurya acuminata* showed greater regeneration at almost all the sites. Regeneration of *Q. lamellosa* and other commonly used species was comparatively greater in the CC than in the OC in the LF. Similarly, *Rhododendron falconeri* and *Rhododendron arboreum* also

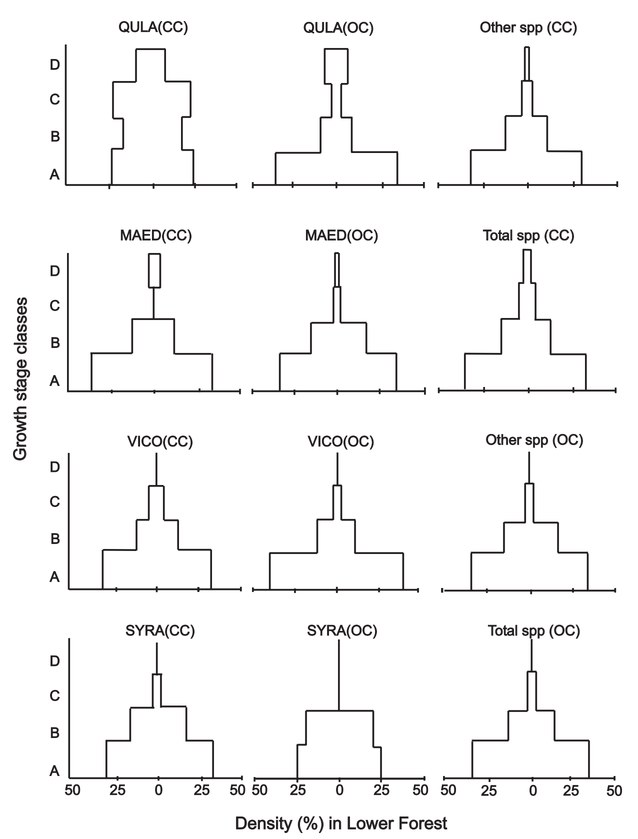


FIGURE 3 Density of tree species at different growth stages (A = seedling, height < 20 cm; B = sapling, height > 20 cm, but diameter < 10 cm; C = small tree, diameter = 10–30 cm; D = large tree, diameter > 30 cm) in the LF. QULA, *Quercus lamellosa;* MAED, *Machilus edulis;* VICO, *Viburnum cordifolia;* SYRA, *Symplocus ramosissima;* Other spp, other species; Total spp, total species; CC, closed canopy forest; OC, open canopy forest.

showed relatively greater regeneration in the CC than in the OC in the UF. Interestingly, *Abies densa*, the dominant species in the UF, regenerated very poorly in both CC and OC forests (Table 4). Canopy trees showed poor regeneration, which was distinctly different in the OC and the CC. The number of regenerating individuals for canopy trees markedly declined in the OC compared with CC forests in both the LF and the UF.

Tree population and structure

Comparative values for tree abundance, ratio of abundance to frequency, density, basal area, and IVI (the sum of relative density, relative frequency, and relative dominance) are given in Tables 5 and 6 (see Chettri et al 2002, www.mrd-journal.org). Compared with the CC, the OC in the LF showed markedly reduced values for IVI and basal area for species that are preferred for firewood. *Q. lamellosa*, *Quercus lineata,* and *Castanopsis* spp showed reduction in IVI values in the OC. *Cinnamomum impressinervium* and *B. sikkimensis* were completely absent in the OC. It appeared that many fodder tree species (*Leucosceptum canum, Sterculia villosa,* and *Acrocarpus fraxinifolias*) were left safely in stands for sustainable lopping. *Abies densa, Acer papilio, Rhododendron grande,* and *Litsae elongata* showed low basal area values and IVI in the OC compared with those of the CC. *R. falconeri* and *C. impressinervium* were absent in the OC in the UF.

Tree population structures of the dominant canopy and subcanopy species are presented in Figures 3 and 4. There are visible differences among the species evident from their preferential use as firewood or fodder. In the LF there was a greater number of small *Q. lamellosa* trees and a fair number of large trees in the CC. On the other hand, substantial reduction in the number of small *Q. lamellosa* trees was recorded in the OC. Most of the dominant and "other species" category also showed substantial reduction in the number of large trees in the OC. The number of small and large trees was markedly reduced in the OC compared with the CC in both the LF and the UF (Figures 3 and 4).

Discussion

Forests remained undisturbed on steeper slopes, and degradation increased near the settlement and tourist camp sites where interference was more pronounced. It was observed that firewood and fodder resources were generally extracted from forests that are easily accessible. Chopping of trees and lopping of branches was more frequent in the OC, which significantly deformed the canopy structure, leading to disruption of regular-dbh-class distribution patterns. Great diversity of the OC in the LF may be the result of invasion by new species in the resultant canopy gaps (Hobbs and Huenneke 1998) or disturbances during the intermediate stage of succession, which favors development of secondary species (Fox 1979). Climax (canopy) species, such as *Quercus* spp, *A. densa,* and *Magnolia* spp regenerated poorly in the forest along the corridor, whereas secondary species performed well. *Symplocos ramosissima* regenerated in both the OC and the CC and has been dominating in areas between 2400 and 2700 m. Canopy opening or canopy species death leads to domination by *S. ramosissima*; this has been confirmed by similar reports elsewhere (Metz 1997). Regeneration of *R. falconeri, R. arboreum,* and *Magnolia campbellii* has been fairly good in the CC in the UF, where extraction pressure on the forest was quite low.

Steep slopes and poor water retention capacity at the sites may be attributed to poor regeneration of *A. densa* (Chaudhry et al 1996). Although the number of seedlings was high for most of the species in all the stands, the sapling survival rate has diminished substantially. The number of both small and large trees also decreased, resulting in irregular tree size distribution in the areas with high anthropogenic pressure on resources. This indicates that with respect to species composition and dominance, forests along the trail show symptoms of low quality more conspicuously, in terms of instability and degradation. The reason for such instability may be selective harvesting of lower-dbh-class trees and a high degree of grazing and trampling along the trail, which causes continued disturbance (Veblen 1992; Singh et al 1997; Singh 1998).

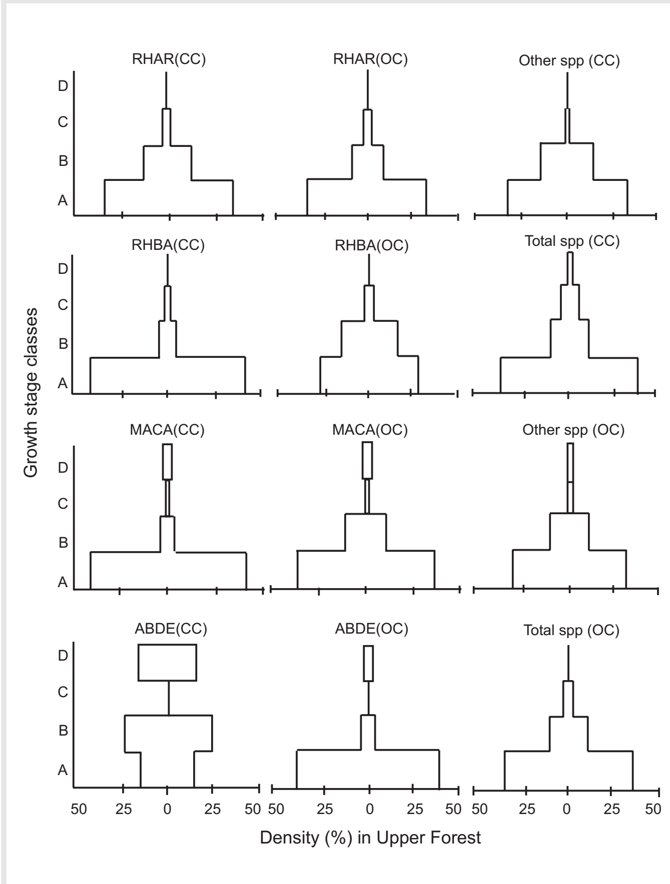


FIGURE 4 Density of tree species at different growth stages (A = seedling, height < 20 cm; B = sapling, height > 20 cm, but diameter < 10 cm; C = small tree, diameter = 10–30 cm; D = large tree, diameter > 30 cm) in the UF. RHAR, *Rhododendron arboreum;* RHBA, *Rhododendron barbatum;* MACA, *Magnolia campbellii;* ABDE, *Abies densa;* Other spp, other species; Total spp, total species; CC, closed canopy forest; OC, open canopy forest.

High extraction pressure in the LF was attributed to greater annual demand for firewood by the community, as well as to inefficient policing and management by forest managers. The inclusion of the entire trekking corridor in the biosphere reserve did not help reduce pressure on the forests. Trekkers numbered in the hundreds initially; their numbers have now risen to about 2000 a year. Combined with a lack of adequate fuel alternatives at the sites, this has led to increased pressure on the trail forests.

In acknowledgment of the importance of conservation in the trekking corridor, a major initiative was launched in the form of the Sikkim Biodiversity and Ecotourism Project. This project provides capacity-building training and conservation awareness programs that promote alternative fuel use for tourism (Rai et al 1998). Codes of conduct with ecofriendly tourism ethics and practices were developed by a community-based conservation organization (the Khangchendzonga Conservation Committee) and the Travel Agents Association of Sikkim. Compliance with these conservation codes was made mandatory for travel agencies, visitors, and the community and was a major step in reducing firewood collection in the corridor.

During the project period, provision of kerosene and liquefied petroleum gas (LPG) for travel agents and communities was facilitated by influencing the decision making at the policy level. As a result, there was a substantial reduction in firewood use, whereas increased use of LPG and kerosene was recorded by tourism enterprises and local households who could afford it during 1997–1998 (Chettri 2000).

Communities in Yuksam and Tshoka are now aware of the importance of resources in the corridor for sustainable development of tourism. The Khangchendzonga Conservation Committee has been actively involved in monitoring compliance with the code of conduct, in participatory monitoring of the resources and wildlife on the trail, and in policing the area along with the Department of Forests to support conservation. It is expected that reduced use of firewood for tourism in the trekking corridor would enhance forest regeneration and reverse the forest degradation process, making tourism sustainable.

Conclusions

Forest-based resources are an integral part of the livelihood of people in the Himalaya. The Yuksam–Dzongri trekking corridor in the Khangchendzonga Biosphere Reserve of Sikkim is endowed with rich biodiversity. Insufficient forest management and policing, unregulated tourism, and population growth have threatened the forest resources and biodiversity of this area for the past 3 decades. The CC forests have been reduced and opened in most parts, especially at lower elevations where human interference was intensive. Extraction of firewood and timber for community use and tourism was observed all along the trekking corridor, although it was more pronounced near the major settlement of Yuksam. Pressure on the forest resulting from tourism has been more distinctly visible at Tshoka, the first designated campsite on the trail. Regeneration of canopy species has been retarded by the invasion of secondary species, which are likely to dominate in the near future.

Firewood extraction along the trekking corridor has had distinct impacts on tree structure, regeneration of canopy tree species, and productivity of woody biomass. Management of trekking corridor forests can promote canopy species regeneration and restoration of old forests. Afforestation with canopy species should be carried out. Compliance with the code of conduct for conservation by tourists, enterprises, and communities, especially concerning the use of alternatives to firewood, can help restore forests and make the destination more attractive and valuable. The Sikkim Biodiversity and Ecotourism Project was an initiative that brought communities, local tourism enterprises, and travel agencies together for conservation. The findings of this study, which is a part of that project, could provide lessons in planning new ecotourism destinations in the Hindu-Kush Himalayan region and other mountainous regions of the world.

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ACKNOWLEDGMENTS

The authors thank the Director, G.B. Pant Institute of Himalayan Environment and Development (GBPIHED), and The Mountain Institute, USA, for facilities. The authors were associated with the Sikkim Biodiversity and Ecotourism Project, which received support from the Biodiversity Conservation Network funded by USAID. IDRC Canada also provided financial support to N.C. Dr Rodney Jackson of The Mountain Institute and Dr S.C. Rai of GBPIHED offered their help at various stages of this work. Facilities provided by ATREE—EHP are also acknowledged.

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