CHAPTER IV

Chapter IV

Human disturbance on forest resources

4.1. Introduction

Among the major resources available to man are lands; comprising of soil, water and habitat for associated plants and animals. However, disturbance or change of natural habitat is the largest single cause of loss of biological diversity (Hannah *et al.* 1995). The use of biological resources should be sustainable because man's existence depends upon their higher productivity (FAO 1994). However, these resources are vulnerable to deterioration and degradation due to improper use. Subsistence farm economy of million of peasants in the tropical Asia is inherently dependent on forests, which form the major source of firewood, fodder and timber. Forest degradation in tropical Asia has been rampant. Most of the tropical mature forests in Asia accounts below standard standing biomass (< 350 Mg ha^{-1}) and only a few mature forests (6%) show biomass estimates over 400 Mg ha^{-1} (Brown & Lugo 1982, Brown *et al.* 1991). Tropical Asia alone has lost 14% of its forest area within a time span of 100 years (from 1850-1950) and it has further shrunk by 15.8% from 1950 to 1980 (WRI & IIED 1987). Forest loss in Southeast Asia was 7% during the same period (Thapa & Weber 1990).

Firewood is reported to support energy requirement of 1.4 thousand million people, and is expected to rise to 2.5 thousand million by 2010 (FAO 1994). In the Himalaya, 76% of the total energy consumption is derived from firewood, due to free and easy access to forest and for simplicity in its use (Openshaw 1980, Wallace 1981, Eckholm *et al.* 1984, Blaikie 1985). Wood is widely used energy source for cooking and heating purposes by the families of most of the tropical Asian countries (Bajracharya 1980, 1983, Lanly 1982, Fox 1984, Mahat *et al.* 1987, Sundriyal *et al.* 1994, Sundriyal & Sharma 1996). Diminishing of the forest resources has been aggravating the pressure on livelihood, directly by causing shortage of firewood and fodder (Thapa & Weber 1990). The ever increasing human and livestock population in rural areas are exerting powerful pressure on land resources to meet the requirements of food, fuel, fodder, timber and other human needs. In the process, over exploitation and improper use of these resources have resulted in the disappearance of forests, erosion of soil and deterioration of fragile ecosystems.

Sikkim possesses 43% of its total geographical area under forest cover of which 34% is dense forest (Anonymous 1994). Majority of the people in Sikkim depend on forests for firewood, fodder, and timber, and substantial portion of these come from agroforestry systems and farm residues. About 5 Mg ha^{-1} of woody biomass is removed for firewood annually from the forests (Sharma *et al.* 1992). The firewood are used by community for different purposes such as cooking (69%), animal feed preparation (9%), house warming (7%), water heating (7%), local wine and beer preparation (6%) and on festivals (2%). Most of the houses are made up of woods and fragmentation of families leads to construction of many new houses each year consuming substantial woody biomass from forests (Sundriyal *et al.* 1994). Balance of land use, resource utilisation and conservation has been recently perturbed in Sikkim due to population growth and fragmentation of farm families (Rai *et al.* 1994). Tourism, a fast growing industry for the state, imparts additional pressure on the resources (Rai & Sundriyal 1997). Firewood demands by tourism and associated activities in the mountains are believed to have considerable impact on the forest vegetation and wild life (Bjonness 1980, Byers 1986, ERL 1989, Gurung 1990, Banskota & Sharma 1994). Though the firewood demand in the area for tourism is seasonal (March-May and September-November), and alternative energy use for tourism purposes has become mandatory, firewood use by support staff and by some travel agents are still continuing.

Collections of firewood and fodder have been the two major factors causing destruction of forests (Thapa & Weber 1990). Firewood consumption in the area has been mainly for meeting community requirements and for supporting tourism based enterprises. A rapid depletion of forest resources has led to environmental degradation all over the Himalaya (Thapa & Weber 1990, Singh & Singh 1992). The balance between natural habitat and human dominated landscapes will determine the future of biological diversity conservation over large areas of the planet. It is therefore, important to map and quantify the degree of human conversion of natural habitats by human interventions including tourism in human dominated landscapes (Hannah *et al.* 1995, Rai & Sundriyal 1997).

4.2. Human disturbance and its consequences

It is unanimously agreed upon the rapid degradation of forest caused by rural populations. Much of the villagers contribute to the degradation due to a combination of increased requirement for the rapidly growing population and open access to resources (Sharachandra 1993). The result imparts immense pressure on the natural resources.

In the present study "human disturbance" refers to resources extracted by human beings directly or indirectly for their subsistence living. Firewood collection, fodder lopping and timber extraction assigns direct interference in which humans are personally involved for such activities. On the other hand, pack animals, seasonal livestock grazing and seasonal movements of animals by herders are indirect interference since pressure is imparted by the animals but as a part for the need for human livelihood. Large-scale commercial and industrial exploitation has immediate visual impacts on forests while pressure exerted by human interference may not be obvious in short period. However, their impact in forest is profound and often they cause irreparable damage to the ecosystem. Effects of firewood collection, fodder lopping, timber extraction and livestock grazing are manifold and cumulative, which directly modify the ecological processes.

Many literatures are available on the impact of human interference on forest in the Himalaya (Friends 1983, Byers & Banskota 1993, Sundriyal *et al.* 1994, Garkoti & Singh 1995, Sundriyal & Sharma 1996, Sharma *et al.* 1998, Uma Shankar *et al.* 1998). Therefore, a careful study of impact in this direction is necessary and the knowledge of functioning to such interference would be important information for management to planners. This chapter deals on (a) resource extraction areas, (b) preferred species for firewood, fodder and timber and their quality, (c) extraction pressure in terms of annual firewood, fodder and timber demands and (d) assessment of disturbance parameters along the corridor.

4.3. Methods

In the preliminary phase of this study, forest use pattern by the communities and their perception regarding the preference of species for firewood, fodder and timber were investigated. An extensive Participatory Rural Appraisal (PRA) technique was applied for information gathering (Pretty *et al.* 1995). Matrix ranking tool from PRA was applied for collection of information on preference and availability of firewood, fodder and timber species. Resource extraction mobility map was used for mapping resources extraction pressure areas including information on grazing regime and NTFP extraction. This information was triangulated with other local persons who were not present at the time of PRA. Frequency of resources extraction was monitored from the trailhead of forests. All the head loads were recorded by their sex, age and the forest from where these were collected. In case of animal used, the numbers of animals were recorded and the quantity was estimated with 60 kg yak^{-1} and 30 kg horse^{-1} as standard weight. A total of 71 days spread over all seasons were randomly sampled for collection during 1997. Frequency of collection was calculated on the basis of number of persons encountered during the sampling.

Preference ranking scores (higher the preference higher the scores) for fodder and firewood species were also evaluated and verified by laboratory analysis. Samples like branches of 2-3 cm diameter of 21 enlisted woody tree species for firewood and 25 species with palatable parts for fodder were collected from the field during December and January 1997-98. The collected samples were brought to laboratory within 36 hours in polythene bags. Fresh weight of samples were determined and then dried in hot air oven at 80^0C for 24 hours. Dry weight was taken for all the samples for estimation of moisture. Firewood density (specific gravity) was determined through water displacement technique from the dry weight. Samples were ground in an electric grinder to pass through 2 mm mesh sieve. Three samples of each species were considered for analysis. Moisture, dry matter content (DM), nitrogen, and crude protein (CP) of fodder species were estimated following Anderson & Ingram (1993). Samples were burnt in an oxygen bomb calorimeter to determine their calorific value (Leith 1973). Ash was determined by weighing 2 gm of samples and burnt in a muffle furnace at 550°C. Quality of any green fodder can be primarily judged on the basis of palatability, DM, CP, and available energy (Saha *et al.* 1997). As calorific value and CP are directly related, and ash content and moisture content inversely, a relationship was developed with the relative values of these components to get the fodder value index (FoVI) by developing the formulae given below for getting the gross idea of fodder quality.

$$\text{FoVI} = \frac{\text{Calorific value (kJ/g) x crude protein (g/g)}}{\text{Ash content (g/g) x Moisture content (g/g)}}$$

Calorific value, ash content, moisture and specific gravity (density) of species were used for calculation of Firewood Value Index (FVI) of different species following the formula given by Purohit and Nautiyal (1986):

$$\text{FVI} = \frac{\text{Calorific value (kJ/g) x density (g/cm}^3\text{)}}{\text{Ash content (g/g) x Moisture content (g/g)}}$$

Firewood consumption patterns by different stakeholders were analysed by weight method following Fox (1984). Firewood was weighed at each of the stratified sampling for households and direct observation for the stakeholders on three separate seasons, namely summer, monsoon and winter. These data were used to estimate the per capita consumption and then multiplied by total member in a household or stakeholders to get daily requirement. The data were standardised on yearly basis. Fodder demand for the total livestock was calculated by standardised consumption rate following Sundriyal (1995). Livestock fodder consumption standard rate used are 1.5 kg day^{-1} for pig, 15 kg day^{-1} for goat, 15 kg day^{-1} for sheep, 25 kg day^{-1} for horse, 30 kg day^{-1} for cattle, 35 kg day^{-1} for dzo and 35 kg day^{-1} for yak. Total fodder demand in the area was enumerated using animal numbers and consumption rate.

Disturbance parameters were checked in the field after triangulation of information gathered from PRA. Four sampling stands, two at lower forest (LF) in the elevation ranging from 1780 to 2350 m amsl (settlement of Yuksam generally depend on this forest) and two at upper forest (UF) in the elevation from 2350 to 3400 m (settlement of Tshoka and tourism enterprises depend on this forest). Nineteen permanent plots measuring 30 x 40 m size were sampled following the procedure of by Sundriyal *et al.* (1994), Sundriyal & Sharma (1996) and Metz (1997). Plots were laid in close canopy forest (>40% canopy cover), that remained relatively unused and distantly located from the settlements, and open canopy forest (<40% canopy cover) that were used and located near the settlements (see Chapter V for detail). Disturbance parameters were measured in 5 x 5 m randomly placed subplots numbering five within 30 x 40 m plots. Number of lopped branches, chopped trees, cattle dung, and trampling impressions were recorded from each subplot. Depth of sandy soil, dry leaf litter, clay and humus were also measured by digging 100 cm^2 pits upto 50 cm depth at the centre of each plot.

4.4. Results

4.4.1. *Forest resources utilisation pattern, preferences and consumption*

Communities of Yuksam practised a well-demarcated pattern for forest resource extraction. Out of the twelve settlements, two namely, Tshoka and Gyachen exclusively and other three partially used the corridor forest. Rest seven settlements used Pahakhola-Thaktu forest, Dubdi forest and Chihan Dara forest for firewood, fodder and timber collection (Fig. 4.1). Apart from these settlements, Himalayan Mountaineering Institute trainees, tourism related enterprises such as individual tourists, travel agents, porters, yakmen and trans-humans (yak and sheep herders) also depended on the natural resources of this corridor. Frequency analysis showed that the firewood collections were mainly made in winter during November to March (Fig. 4.2). Tourism enterprises (travel agencies and the support staff) related collection of the firewood occurred mainly in two peak tourist seasons during March to May and August to December. Chopped trees frequency analysis showed a low pressure on 10-20 cm diameter at breast height (DBH) class, medium pressure in 50-60 cm and high pressure on 20-50 cm class (Fig. 4.3).

4.4.1.1. *Firewood, fodder and timber - Species preference*

Baseline information gathered using PRA tools showed that the communities living at Yuksam and Tshoka used a wide variety of plant species for firewood, fodder and timber (Tables 4.1 & 4.2). Due to ability to recognise and knowledge on quality of species, the communities living in these areas practised resource collection with preference in species and compensated with other species if the preferred species were not available.

Preference for pairwise ranking on firewood, fodder and timber are presented in Table 4.1 and Table 4.2. Eleven woody tree species were listed as widely used firewood from the pair wise preference ranking at Yuksam. *Quercus lamellose* ranked the highest followed by *Schima wallichii, Eurya acuminata,* and *Castanopsis hystrix, Beilschmiedia sikkimensis* and *Prunus cerasoides.* Likewise, 22 plant species were enlisted with their preference ranking for fodder from Yuksam. Among these species 59% were tree fodder, 14% shrubs, 18% herbs and 9% climbers. *F. roxburghii* was the highest ranked species followed by *Pavetta indica, Saurauia napaulensis* and *Ficus nemoralis.*

Species preferences were quite different for the Tshoka community as they depended on cool temperate and sub-alpine species. *Q. lamellosa* ranked higher for firewood followed by *Q.*

lineata, Rhododendron arboreum and *Betula alnoides. Sorbus* sp. and *Symplocos ramosissima* ranked as the least preferred species. *Litsae elongata, Arundanaria* sp. and *Dedrocalamus* sp. have high ranking as fodder plants. *Acer laevigatum, A. oblongum* and *Magnolia* sp. were among the least preferred species. Among the timber species, *Michelia exelsa* ranked the highest followed by *Juglans regia* and *Q. lamellose* by the Yuksam community and *Abies densa* as the highest followed by *Acer oblongum* and *Q. spicata* by the Tshoka community. *Alnus nepalensis* although being the least preferred species; it was used widely because of its availability. At Tshoka, *B. alnoides* and *Magnolia campbellii* were among the least preferred species.

4.4.1.2. Firewood and fodder–Quality

The data collected on firewood characteristics of 21 widely used woody tree species from Yuksam and Yuksam-Dzongri trekking corridor is presented in Table 4.3. Almost all the rhododendrons were found to have high calorific value. Among them, *Rhododendron fulgen* showed the highest value followed *by R. grande, R. decipiens, R. arboreum, R. falconeri* and *R. barbatum*,. Ash content was the lowest in *R. lanatum*. Comparatively, *R. decipiens, R. barbatum, R. fulgen* and *R. arboreum* had higher ash content. Among the other species, higher calorific value was found in *P. cerasoides* followed by *Schima wallichii, C. hystrix* and *Quercus* *lamellose*. Ash content among these species was the lowest in *Eurya acuminata* and *Symplocos ramisissima*. High moisture content was recorded in *S. ramosissima* and *S. wallichii*. Overall, biomass-ash ratio was the highest for *R. lanatum* followed by *R. decipiens, R. barbatum,* and *R. arboreum* and the lowest value was in *Acrocarpus fraxinifolius*. Among the species with high calorific value, *R. lanatum* had the highest wood density (0.78 g cm^{-3}). Among the rhododendrons, *R. arboreum* showed the highest FVI value with low ash content, high density and low moisture. Other three species of rhododendrons namely, *R. lanatum, R. decipiens* and *R. barbatum* also had higher FVI values. Among the other species, *Quercus* sp., *Symingtonia populnea* and *P. cerasoides* were found to be highly desirable firewood when compared with *E. acuminata, Q. lamellose* and other non-rhododendron species. The least desirable species were *S. ramosissima, A. fraxinifolius* and *Alnus nepalensis* due to their low density and high ash contents (Table 4.3). Basically all the species with high calorific value showed low nitrogen content than the species with low calorific value.

Table 4.4. shows some selected fodder species, preferred and widely utilised by the local community of Yuksam with their calorific and fodder values. Among the 25 selected fodder species, 40% were the tree fodder, 24% shrubs, 28% herbs and 8% climbers. Among these species, the highest calorific value was in *Crysopogon*

gryllus followed by *Arundanaria hookeriana, Brassaiopsis mitis, Prunus cerosoides* and *Thysanolaena maxima.* Tree leaves were found to contain high dry matter (DM) than shrubs, herbs and climbers. For example, 40% of tree fodder contained more than 40% DM compared to 33% in the shrubs and only 29% in herbs. The highest DM containing trees, shrubs, herbs and climbers were *Quercus lamellose, Glochidion acuminatum, Quercus* sp (trees), *Arundanaria* spp. (shrubs), *Imperata cylindrical* (herb) and *Ichnocarpus frutecens* (climber). Majority of species contained > 10% ash in the DM. Species with high protein content (>10%) were nearly 40% in the tree species, 50% in shrubs, 29% in herbs and 100% in the climbers. Fodder value index showed that *Quercus* sp. had the highest value followed by *I. frutecens, F. roxburghii, Litsae elongata* and *Q. lamellosa.* Species such as *A. hookeriana, T. maxima, Brassaiopsis mitis, Saurauia nepaulensis* and *Ficus nemoralis* showed moderate values (Table 4.4).

4.4.1.3. Firewood, fodder and timber -consumption

Collections of firewood from forests are mainly made during the winter season. Frequency of collection was recorded highest during the month of January and minimum in September (Fig. 4.2). The data from the field revealed that frequency of chopping trees for firewood was the highest for medium sized trees followed by small tree and large trees (Fig. 4.3). The total demand for the firewood for community as well as other tourism enterprises was estimated to be 2433 Mg $year^{-1}$. About 55% of the total demand is met from trail forests both for community and tourism purposes (Table 4.5). Domestic cooking is the major consumer of fuelwood followed by water heating and other purposes. Consumption ranges from 2264 Mg $year^{-1}$ by community and lowest of 1.02 Mg $year^{-1}$ by pack animal operator. On an average the hotel and lodges consumed about 40 to 50 kg of fuelwood per day. A large quantity of fuelwood was used by HMI during training courses for cooking and otherwise (Table 4.5). There were visible changes in the fuelwood consumption pattern among the stakeholders during different seasons (Table 4.6). Higher fuelwood consumption was recorded during the winter season for almost all the stakeholders. The estimated value revealed that community alone used three times more fuelwood in winter compared to the summer (Table 4.6).

Four sources of firewood supply were identified in the study area such as (a) homestead surroundings, (b) privately owned wooded (agroforestry system) area, (c) community used forest (khasmal), and (d) reserve forest and biosphere reserve. Both private owned forest and government forest met most of the demands of firewood (Fig. 4.4). About 76% of firewood was procured from government forests including biosphere reserve and only 21% came as support from the private forest. Homestead surroundings provided *Jhikra* (3%) that included portion of old wooded fences, dried bamboo pieces as it catches fire soon, and agricultural residues as maize and millet stacks, especially for livestock feed preparation. About 79% of the total household depend upon the firewood for cooking and other purposes followed by 14% of the households on kerosene oil, 4% on electricity and 3% of the household depend on LPG.

Amount of the firewood consumption was the highest in winter (29±10.1 $kg^{-1}day^{-1}family^{-1}$) and lowest in summer (18±6.9 $kg^{-1}day^{-1}family^{-1}$). The mean daily consumption of the wood was found 25.5 $kg^{-1}day^{-1}family^{-1}$ for an average household size of 6.28 individuals with per capita of 3.45 kg at lower elevation and 4.17 kg at higher elevation.

On the basis of standard values for livestock, the total demand of fodder was found 1209 Mg yr^{-1} for the entire livestock present in the study area (Table 4.7). During 1996-98, a net increase of 63% fodder demand was estimated. Fodder demand for cattle was the highest (41%) followed by sheep (21%) and goat (14%). The demand for dzo, yak, pig and horses were respectively 13%, 8%, 1% and 2% of the total.

Large number of trees with <10 cm DBH were used as timber for house construction and renovation just in a time interval of 3-5 years (Table 4.8). Use of medium sized trees (20-40 cm DBH) and large trees (30-70 cm DBH) were comparatively low and in greater time interval of 5-7 years and 15-25 years, respectively.

4.4.2. Disturbance parameters

Values of disturbance parameters and their standard deviations are given in Table 4.9. Number of lopped branches and chopped trees were high in the open forest condition and low in the close canopy forest. Other indicators of disturbance like depth of humus, depth of dry leaf litter and depth of clayey soil were higher in the dense forest showing less interference. Trampling impression and dung numbers were higher in open forest condition where animals were usually stalled overnight.

4.5. Discussion

People of Yuksam use four main forest areas for resources. Compared to other three forests, high pressure was observed in the KBR corridor forests. A wide variety of plant species was used by their preference as firewood, fodder and timber from the farmland and forests. Dependency on forest for firewood was higher compared to other parts of Sikkim (Sharma *et al.* 1992). Forests have immense pressure for firewood, fodder and timber as a settlement is located at the vicinity of the biosphere reserve and tourism sector is flourishing in uncontrolled and unmanaged direction.

Local preference of firewood is an age-old trend in the Himalaya, but assessments of such knowledge with scientific support are countable (Purohit & Nautiyal 1986). For ideal firewood, high heat of combustion, high density of wood, low ash contents and other combustion properties are most desirable. Also, chemical analysis can indicate the gross feeding potential of the feeding stuff (Narayanan & Dabadhao 1972) and provides important information about their qualities (Bajracharya *et al.* 1985, Purohit & Nautiyal 1986). It is therefore, felt important to assess the qualities as per preference. The pattern of species preference for use depends upon the quality of the firewood, season of the collection and time required for drying it before use. People of Yuksam depend on the reserve for selective species of their choice for firewood or timber. The selection of high quality species for fuelwood, fodder and timber has declined the number of such trees along the corridor. On the other hand, Tshoka community completely depended on the reserve for all forest based resource requirements.

Among the temperate species *Quercus* sp. and *S. populnea* were found to have high FVI and almost all the rhododendrons from sub-alpine forest corresponded with the preference ranking. High ranked species for warm-temperate and cool temperate-sub alpine forest matched with the scientific properties. Similar study was also carried out in the Central Himalaya (Purohit & Nautiyal 1986). Nitrogen contents in almost all the lower ranking species were higher. These attributed that higher nitrogen contents emit more nitrogen oxides from the wood during combustion reducing the acceptability as good wood (Purohit & Nautiyal 1986, Nautiyal & Purohit 1988). Due to low ash content, high density and low moisture, *R. arboreum* was found to be the most desirable firewood with highest FVI value.

Among the enlisted species for fodder from Yuksam, all the higher ranked species were tree fodder except *I. Frutecens*. *Quercus* sp, although have high fodder values were not used commonly and their preference ranking was not higher. However, in the Central Himalaya *Quercus* is regarded as preferred fodder generally in winter under crises when other fodder plants were not amply available (Purohit & Sammant 1995). Shrubs, herbs and climbers showed comparatively low preference ranking as also reported by Bajracharya *et al.* (1985). This is attributed to the seasonal availability of species. Among the 25 fodder species enlisted *Quercus* sp., *I. frutecens, F. roxburghii and L. elongata* were found to have high quality of fodder with comparatively high calorific value and other characteristic (see also Saha *et al.* 1997, Rajhan 1977). In spite of high calorific values, many shrubs and herbs species had low feed value due to higher moisture contents and low protein. Calorific values of fodder were found to have wide variation between species to species. The present findings revealed that the quality of fodder does not depend solely on one parameter like calorific values or the protein contents, but on the combination of qualities, which resulted in deciding the high feed value of fodder. The result corresponded with the report made by Bajracharya *et al.* (1985) and Bajracharya & Chaudhary (1986). Chemical composition of fodder differed from place to place as observed from reports of Mamlay (Sharma *et al.* 1992), other parts of Sikkim (Sinha 1982, Balaraman 1987, Balaraman *et al.* 1990, Balaraman & Goyal 1991, Saha *et al.* 1997) and Nepal (Bajracharya *et al.* 1985, Bajracharya & Chaudhary 1986). This attributed to ecological factors including soil and climate, which influence the chemical composition of fodder plant (Wolf 1972). Most of the tree species ranked higher as fodder by the local community corresponded with > 30% dry matter and < 10% ash (Rajhan 1977), suggesting that the local knowledge of preference are compatible with scientific attributes for the selection of better fodder. Inspite of high crude protein content and comparatively high calorific value, the fodder value of *F. nemoralis* was found relatively low due to high ash content. Chemical properties and fodder value index of species such as *F. roxburghii, F. nemoralis* and *P. cerasoides* matched with the higher ranking preference of these species by the people. Other species such as *Artemesia vulgaris, E. sessile* and *Rhaphidophora* sp, showed low rank in preference as well as low values in chemical properties. The sequence of preferences was not in the order of fodder values showing variation from the matrix scores. This variation brought some doubt for chemical properties and preference ranking. Therefore, the chemical properties and preference rank agreement seems to be questionable for most of the fodder species, thus the authenticity on the information of quality of plants provided by the community should be considered with caution (Bajracharya & Chaudhary 1986).

Firewood collection and stocking for rainy season by the villagers have been common in the area. A huge amount of firewood and fodder extraction has been recorded in the area. Firewood was collected either from felled trees or from chopped branches. Collections are made by head-loads either by putting into a *Doko* (bamboo basket) or by tying with rope or bark of Argeli (*Edgeworthia gardeneri*). Men, women, children and even dzos are engaged for carrying the firewood loads from the forest to villages. The pressure for natural resources on the trail forest is comparatively higher than the other surrounding forests. Tourism activities and the pressure of different stakeholders are also noteworthy. Such pressure at the high altitude area may result severe degradation in future bringing about considerable impact on the forests and wildlife (Bjonness 1980, Byers 1986, Baskota & Sharma 1994).

Present study revealed that the forests remained undisturbed at steeper slopes and forest degradation has increased at the forests where human interference was more pronounced. Such areas are located at gentle slope and near the human habitation or campsites (personal observation). This indicates that the resources were generally used from the forest that was situated in gentle slopes. This was mainly because of easy access to forest sites of gentle slope (Brown *et al.* 1991). Chopping of trees and lopping of branches whose numbers were higher at disturbed areas have significantly disrupted the canopy structure leading to open conditions.

4.6. Conclusion

Forest based resources are the integral part of the Himalayan livelihood. Yuksam-Dzongri trekking corridor of the Khangchendzonga Biosphere Reserve in Sikkim has faced immense human pressure on its natural resources in the recent years. Rapid increase in tourist number and livestock has caused threat to the forest resources of the area. Large amount of firewood, fodder and timber extraction by the community as well as tourism enterprises is deteriorating the quality of forests. Selection of species by preference is widely practised in the area. Interestingly, local preference and the chemical properties have shown that the local knowledge is compatible with scientific attributes for most of the species. Extraction of firewood, fodder and timber for community and tourism purposes was observed all along the trekking corridor but has been more pronounced near the major settlement of Yuksam. Tourism related pressure on the forest was distinctly noticeable at Tshoka, the first camping site on the trail. Removal of selective canopy species for firewood, fodder and timber has changed the forest quality.

Indicators of disturbances are pronounced at the open forest due to the result of immense human as well as grazing pressure. Therefore, management of trekking corridor forests should be oriented in such ways that pressure on preferred canopy species is minimised. Area should be encouraged for assisted natural regeneration and simultaneously discouraging continued pressure. Enterprises and community should be made aware of the legal status of KBR. The use of alternative sources of energy should be encouraged for improvement of the forest conditions to make the area more attractive and valuable in terms of biodiversity.

Table 4.1. Pair-wise ranking scores of preferred species used as firewood, fodder and timber at Yuksam, west Sikkim.

Place/species (local name)	Firewood	Fodder	Timber
Acer laevigatum (Putli)	-	4	4
Alnus nepalensis (Uttis)	2	-	1
Amoora wallichii (Laali)	-	5	-
Artemesia vulgaris (Teteypaty)	-	9	-
Arundinellan nepalensis (Kharuki)	-	16	-
Beilschmiedia 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 roxburghi (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

Table 4.2. 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 ramisissima (Kharane)	1	3	-

Tabble 4.3. Wood energy, density, ash and firewood values index (FVI) of 21 woody tree species of Yuksam and Yuksam-Dzongri trekking corridor.

Species (local name)	Calorific value (kJ/g)	Ashfree calorific value (kJ/g)	*Density* (g/cm^3)	Biomass /ash ratio	Moisture (%)	Ash (%)	N (%)	FVI
Rhododendron arboreum (Lali guras)	19.63	19.72	0.69	222.22	25	0.49	0.21	11057
Rhododendron lanatum (Bhutle guras)	18.79	18.82	0.78	625.00	54	0.26	0.22	10439
Rhododendron decipiens (Jhukaune guras)	19.81	19.87	0.67	303.03	49	0.33	0.26	8202
Rhododendron barbatum (Lal chimal)	17.84	17.91	0.75	263.16	47	0.38	0.29	7492
Quercus sp (Ainte)	17.72	17.81	0.77	196.07	41	0.51	0.40	6525
Rhododendron fulgen (Chimal)	20.10	20.20	0.62	217.39	45	0.46	0.17	6020
Symingtonia populnea (Pipli)	17.78	17.92	0.89	129.87	45	0.77	0.17	7645
Rhododendron falconeri (Korling)	19.21	19.30	0.65	217.39	49	0.46	0.17	5539
Rhododendron grande (*Patle korling*)	19.98	20.15	0.68	120.48	42	0.83	0.19	3897
Prunus nepualensis (Arupate)	18.32	18.46	0.76	123.46	47	0.81	0.33	3657
Eurya acuminata (Jhiguni)	16.64	16.75	0.72	151.51	50	0.66	0.37	3630
Quercus lamellose (Bajrant)	18.25	18.47	0.86	86.21	39	1.16	0.31	3469
Prunus cerasoides (Panyun)	19.93	20.15	0.73	89.28	44	1.12	0.27	2952
Viburnum cordifolium (Asare)	16.64	16.84	0.69	87.71	38	1.14	0.47	2650
Beilschmiedia sikkimensis (Tarsing)	15.63	15.79	0.68	102.04	41	0.98	0.25	2645
Castanopsis hystrix (Jat katus)	18.49	18.78	0.88	64.51	43	1.55	0.38	2441
Symplocos glomerata (Kholmen)	11.81	11.89	0.66	151.51	54	0.66	0.22	2187
Schima wallichii (Chilaune)	19.15	19.41	0.96	73.53	66	1.36	0.23	2048
Symplocos ramosissima (Kharane)	15.09	15.24	0.67	149.25	76	0.97	0.30	1371
Acrocarpus fraxinifolius (Mandane)	16.05	16.46	0.58	39.52	48	2.53	0.32	766
Alnus nepalensis (Uttis)	15.87	16.25	0.45	42.55	54	2.35	0.33	563

Table 4.4. Leaf energy, nutrients and fodder value index (FoVI) of 25 widely used fodder species of Yuksam and Yuksam-Dzongri trekking corridor.

Species (local name)	Calorific value (kJ/g)	Ashfree calorific value (kJ/g)	Moisture (%)	Dry matter (%)	Ash (%)	Nitrogen (%)	Crude protein (%)	FoVI
Quercus sp. (Ainte)	17.36	17.93	51.8	48.2	3.2	1.53	9.6	101
Ichnocarpus frutecens (Dudhe lahara)	18.86	19.6	64.4	35.6	3.8	1.88	11.7	90
Ficus roxburghii (Nebaro)	18.60	19.53	66.7	33.3	4.8	2.35	14.7	85
Litsaea elongata (Pahenli)	19.35	20.69	57.8	42.2	6.5	2.25	14.1	73
Quercus lamellosa (Bajrant)	18.23	17.06	35.0	65.0	6.4	1.24	7.7	63
Arundanaria hookeriana (Parang)	20.85	22.15	52.0	48.0	5.9	1.38	8.6	58
Thysanolaena maxima (Amliso)	20.04	21.99	62.0	38.0	8.9	2.54	15.8	57
Brassaiopsis mitis (Phutta)	20.23	21.32	72.2	27.8	5.1	1.38	8.6	47
Crysopogon gryllus (Salimo)	22.66	24.68	60.0	40.0	8.2	1.41	8.8	41
Saurauia napaulensis (Gagoon)	18.23	20.14	61.1	38.9	9.5	2.09	13.1	41
Imperata cylindrica (Seeru)	18.92	20.45	53.4	46.6	7.5	1.36	8.5	40
Ficus nemoralis (Dudhilo)	19.92	22.42	70.0	30.0	11.2	2.24	14.0	36
Pantapanax leschenaultii (Chinde)	19.11	20.64	63.9	36.1	7.4	1.36	8.5	34
Bambusa nutans (Malla Bans)	19.23	21.06	66.2	33.8	8.7	1.42	8.87	30
Aconogonum molle (Thotne)	19.98	22.6	67.5	32.5	11.6	1.78	11.1	28
Prunus cerasoides (Panyun)	20.04	22.59	67.7	32.3	11.3	1.69	10.6	28
Arundanaria racemosa (Mallingo)	18.86	22.05	43.3	56.7	14.5	1.37	8.6	26
Glochidion acuminatum (Lati kat)	17.23	19.21	53.7	46.3	10.3	1.30	8.1	25
Solanum aculeatissum (Bhede ghans)	18.61	20.63	61.7	38.3	9.8	1.26	7.9	24
Elastostemma sessile (Thulo gagleto)	15.73	17.11	77.3	22.7	8.1	1.56	9.7	24
Cauteleya spicata (Pani saro)	18.04	20.31	78.8	21.2	11.2	1.78	11.1	23
Artemesia vulgaris (Tetey pattey)	17.17	19.33	75.9	24.1	11.2	1.70	10.6	21
Rhaphidophora sp. (Kanchirna)	18.17	22.21	76.0	34.0	12.6	1.69	10.6	20
Eragrostis tenella (Banso)	17.67	21.42	54.2	45.8	17.5	1.46	9.12	16
Leucanthus pedicularis (Sanu gagleto)	14.73	18.69	75.5	24.5	21.2	1.94	12.13	11

Table 4.5. Fuelwood consumption for different purposes by stakeholders

Stakeholder	Purposes: Cooking ($Mg\ yr^{-1}$)	Water-heating ($Mg\ yr^{-1}$)	Other purposes ($Mg\ yr^{-1}$)	Total ($Mg\ yr^{-1}$)
Community	1896	260	109	2264
Hotel/lodges	86	12	3	100
HMI	37	6	0.2	44
Travel agent	6	1	0.2	7.2
FIT's	1.4	0.3	1	1.9
Pack-animal operator	0.8	0.08	2	0.98
Porter	13	0.6	2	15.6
Total	2040.2	279.9	116.5	2432.68

HMI = Himalayan Mountaineering Institute, FIT's = Free and independent trekkers

Table 4.6. Stakeholder wise seasonal fuelwood consumption pattern

Stakeholders	Consumption (Mg day^{-1})			Average (Mg day^{-1})	Annual (Mg day^{-1})
	Summer	Rainy	Winter		
community	378.32	756.64	1128.76	6.20 [1]	2264
Hotel/lodges	16.72	33.45	49.90	0.27 [2]	100
HMI	2.30	13.07	28.51	0.24 [3]	44
Travel agent	0.16	3.40	3.56	0.010 [4]	7.2
FIT's	0.65	0.00	1.30	0. 001 [5]	1.9
Pack-animal operator	0.086	0.41	0.53	0.002 [6]	0.98
Porter	280	6250	8.85	0.002 [7]	15.6

1, 2: Community and hotel consumption per day 3, 4: Per group, 5, 6, 7: per person

Table 4.7. Livestock number, increase during 1996-1998 and fodder consumption estimation from Yuksam and Yuksam-Dzongri trekking corridor.

Livestock	Years		Fodder consumption ($Mg\ yr^{-1}$)	Increase in fodder consumption (%)
	1996	1998		
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 4.8. Timber use pattern of the 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

Table 4.9. Disturbance at two forests conditions along Yuksam-Dzongri trekking corridor. Values are mean ±SE

Disturbance parameters	Forest conditions	
	Open forest	Close forest
Chopped Branch (per ha)	15.68±3.68	4.96±0.16
Chopped Tree (per ha)	14.40±2.88	0.80±0.52
Naturally fallen tree (per ha)	7.20±4.16	6.72±2.21
Cow dung (per 25 m^2)	1.63±0.25	0.30±0.06
Dzo dung (per 25 m^2)	0.58±0.12	-
Horse dung (per 25 m^2)	0.13±0.07	-
Sheep dung (per 25 m^2)	0.40±0.23	-
Trampling (per 25 m^2)	77.27±9.87	21.60±2.7
Dry litter (depth in cm)	0.73±0.31	4.50±0.58
Humus (depth in cm)	0.40±0.21	2.62±0.28
Clayey soil (depth in cm)	1.25±0.94	5.22±0.64

\- Not found

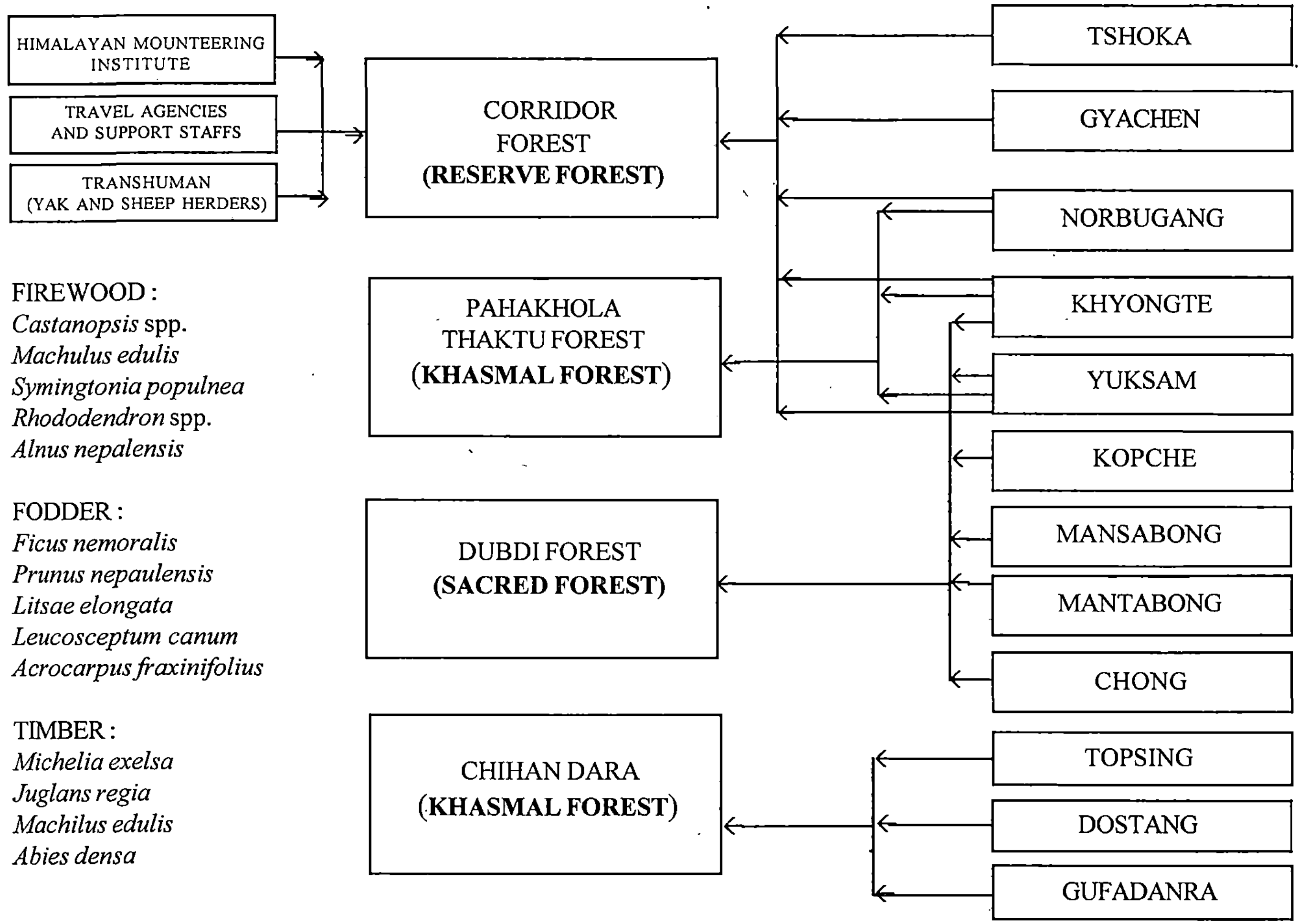

Fig. 4.1. Tourism/HMI, transhuman and settlements based user groups of firewood, fodder and timber and their linkage with four major forest locations surrounding Yuksam and along Yuksam-Dzongri treeking corridor in Khanchendzonga Biosphere Reserve. Some of the preferred and utilized species of firewood, fodder and timber are listed.

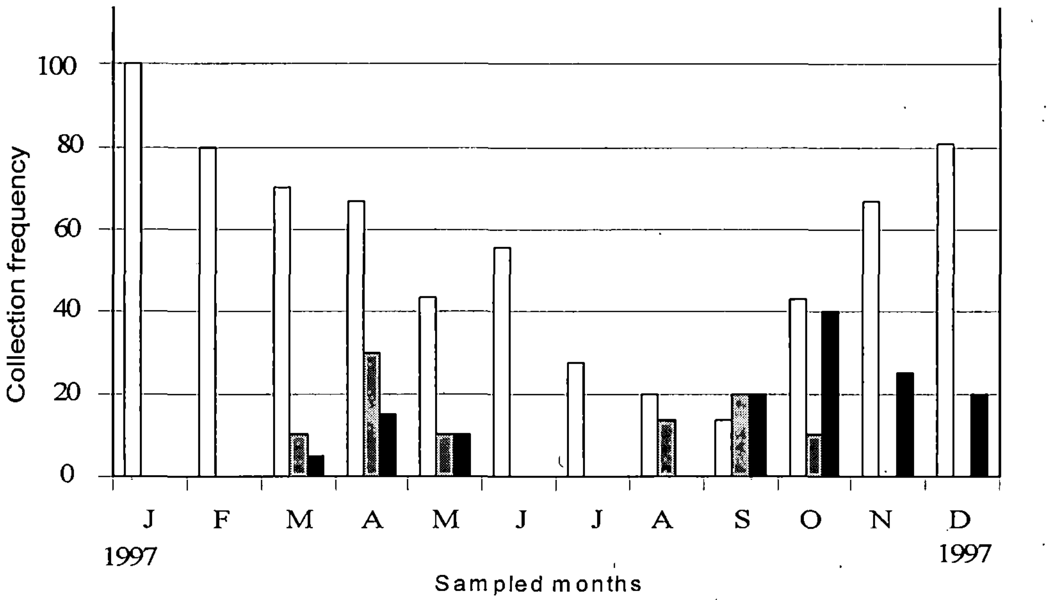

Fig. 4.2. Monthwise fuelwood collection frequency of community, portor and tourism agencies along Yuksam-Dzongri trail. Frequency is expressed in percentage calculated based on collection encounter by authers during field visits. Blank block = Community, grey shaded = porter and dark shaded = Tourism agencies.

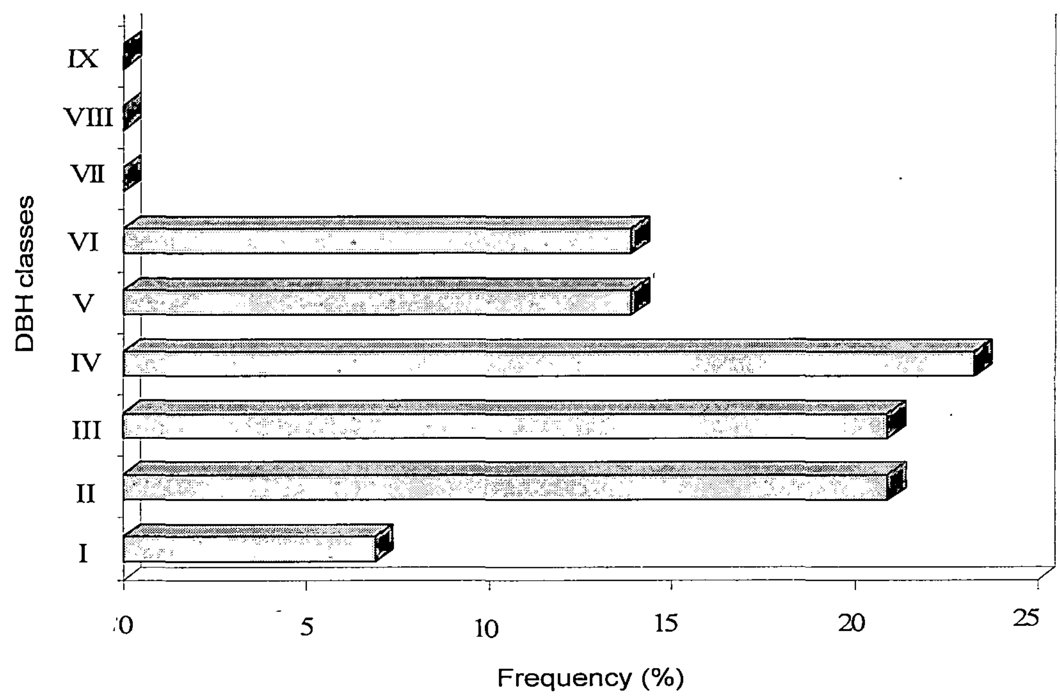

Fig. 4.3. Chopped tree frequency of different DBH classes showing low pressure (< 5%), medium pressure (5-15%) and high pressure (>(15%) on medium sized (20cm-50cm) tree along Yuksam-Dzongri trail. DBH class (cm) I = 10-20, II = 20-30, III = 30-40, IV = 40-50, V = 50-60, VI = 60-70, VII = 70-80, VIII = 80-90 and IX = 90-100.

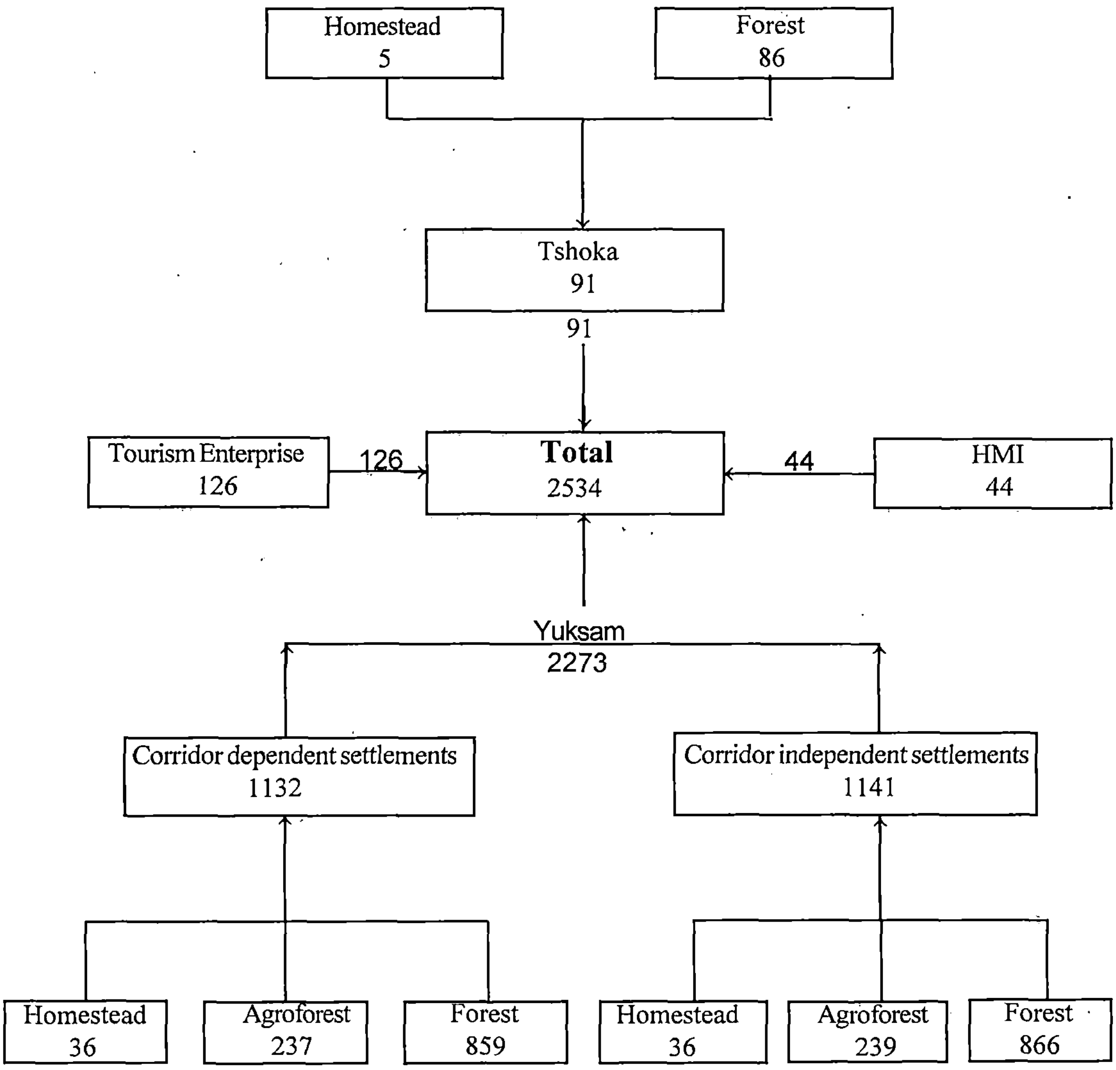

Fig. 4.4. Annual firewood consumption (Mg) from different landuse sources for Yuksam and Tshoka settlements and non community use (tourism and Himalayan Mountaineering Institute courses) along Yuksam-Dzogri forest corridor.