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Research Article

Fuelwood Consumption by Villagers in Different Altitudinal Gradient: A Case of Takoligad Watershed of Garhwal Himalaya, India

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Abstract

The present study deals with the biomass use pattern by villagers along different altitudinal gradient during three seasons. Fuelwood used in watershed for different purposes such as cooking, boiling water and space heating. Preferred and commonly used species, emission of green house gasses due to combustion and alternative fuel sources were also examined. 69.33 % LPG (Liquid Petrolium Gas) was estimated in the study area but most of the families use LPG only for preparing tea during guest visit. Overall average fuelwood consumption (Kg/household/day) at three altitudinal zones in three different season was 6.58 in summer, 10.80 in winter and 6.52 in monsoon (Low 500-1000 m asl), 7.34 in summer, 12.72 in winter, 7.28 in monsoon (Middle 1000-1500 m asl) and 9.66 in summer, 14.42 in winter and 9.28 in monsoon (High 1500-2000 m asl). The sampled household complained of decline in the availability of fuelwood species in the nearby areas. The most preferred species for fuelwood were: Alnus nepalensis, Quercus floribunda, Pinus roxburghi, Rhododendron arboretum, Rhus purviflora and Toona ciliata. The information in this communication could be utilized for developing suitable region-specific and need-based alternative strategies for achieving sustainable fuelwood management at the micro-level.

Keywords: *Fuelwood consumption, Biomass, Bioenergy, Preferred fuelwood, Garhwal Himalaya*

Introduction

Biomass remained the principal component of rural domestic energy in India and most of the developing countries. A large part of the rural population in developing countries like India meet more than one third of their total energy demand, principally in the domestic sector (FAO, 2007; Vasudevan and Santosh, 1987; Natarajan 1985). Biomass accounts for approximately 14% of total energy used globally and is the largest energy source for the three-quarters of the world's population who live in developing countries. Among the various forms of biomass, fuelwood is the most attractive one and occupies a predominant place in the rural energy budget of the country (Kataki and Konwer 2002). Bioenergy is therefore nested at the intersection of three of the world's great challenges energy security, climate change, and poverty reduction and has received an enormous amount of attention in the past few years (FAO 2007). The scenario calls for proper biomass planning, especially in the Himalaya, as almost 90% energy demand is met with biomass resources (Sharma *et al.* 1999).

Fuelwoosd is the only source of energy for many people living in the mountains (Sundriyal and Sharma, 1996) because it is freely and easily accessible and simple to use (Blaikie, 1985). Commercial fuel is beyond the reach of the rural communities due to their poor socio-economic conditions (Kumar et al., 2009). Traditionally, people of the Himalayan region have been fulfilling their energy needs almost entirely from forests (Bhatt and Sachan 2004). According to one estimate, firewood accounts for over 54% of all global harvests per annum, suggesting a significant forest loss (Osei, 1993; Wahab *et al.*, 2008).

Due to an ever increasing population, fuelwood consumption is increasing rapidly in the watershed area. The intense use of forest resource, however, has put woody species in different regions of the world at risk (Dahdouh-Guebas *et al.*, 2000; Medeiros, 2011; Walters, 2005). The per capita annual consumption of dry wood in various parts of the Himalayas ranges between 500 to 1200 kg per capita per annum(Campbell and Bhattarai, 1984; Metz, 1990). This level of fuelwood consumption has resulted in over exploitation of natural resources; consequently, the Himalayan region is experiencing scarcity of fuelwood.

In Garhwal Himalaya, about 77.4% of the total human population is rural (Anonymous, 1991). Fuelwood that is collected from nearby forests is the only source of energy in this region (Bhatt and Badoni 1990). Commercial fuels are beyond the reach of most of the inhabitants, due to their poor socio-economic

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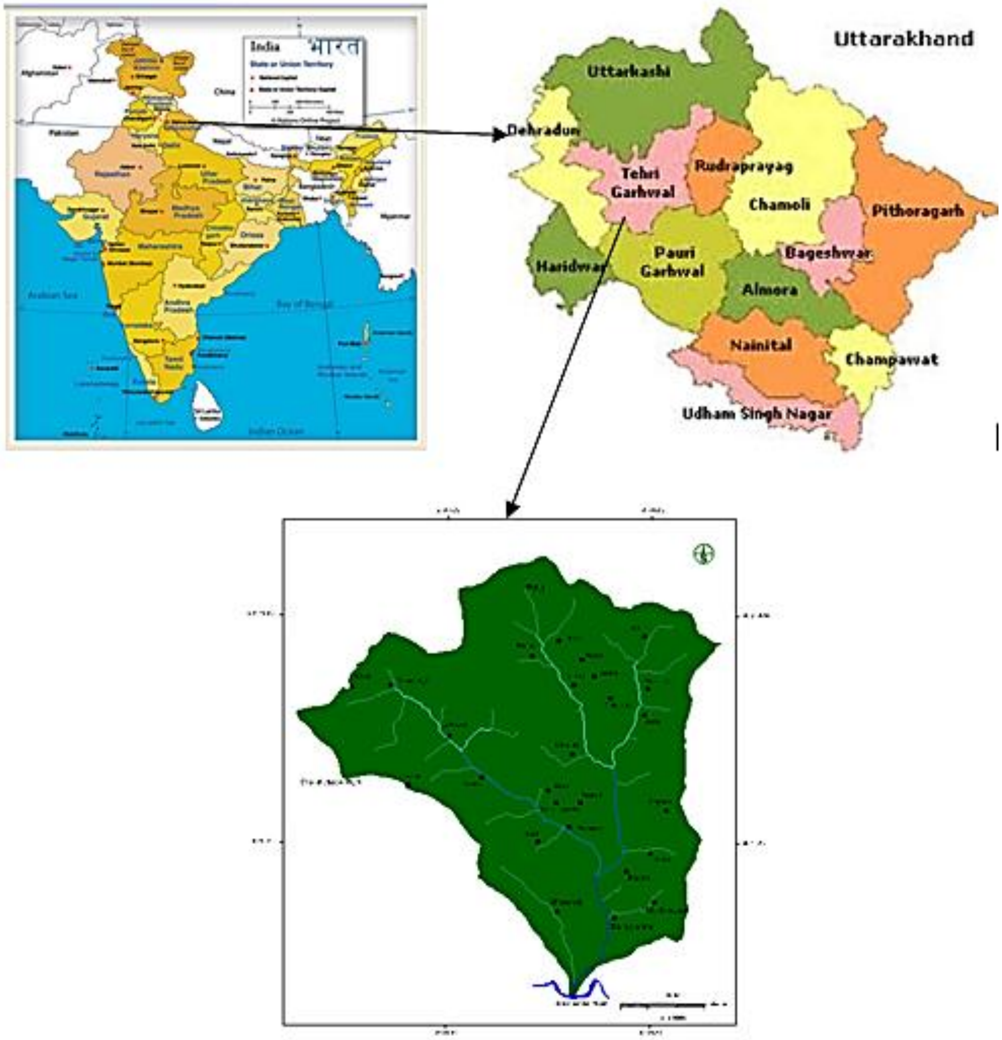

Figure 1: Map of the study area

conditions, inaccessibility, sky-rocketing prices and limited supply of these resources. The commercial energy (kerosene and electricity) consumption consists of only 1.41% of the total (Kumar, 2005). Fuelwood use by communities and the commercial sector has been one of the reasons of continuous destruction of forests. In this part of Garhwal Himalaya, with increasing altitude, forests of different compositions are found, and so different plant species are used at three different altitudes as fuel for cooking, lighting, boiling of water, and space heating (Bhatt and Todaria, 1990).
The information on fuelwood consumption pattern in Himalaya is abundant (Bhatt and Sachan, 2004; Bhatt *et al.,* 1994). The Himalayan communities are unmindful of the possible consequences of over exploitation of forest resources. These communities make extensive collection of fuelwood for cooking, space heating and boiling water without understanding future consequences. The present work focuses on the distribution and utilization patterns of fuelwood species, the quantity harvested on seasonal basis and information on the preference of woody species (trees and shrubs) by local communities at different altitudes in Takoligad watershed.

Study area

The present study was carried out along the altitudinal gradient of Takoligad watershed, Tehri Garhwal district of Uttarakhand, India (Fig 1). Takoligad watershed is situated in the North-eastern part of Garhwal Himalayas between 30^0 14’ to 30^0 23’ N latitude and 78^0 37’ to 78^0 46’ E longitudes occupying an area of 131.43 Km^2. The watershed comprises of a range of altitudinal gradient ranging from 550 m asl to 2301 m asl. The watershed lies in the upper catchment of the Alaknanda River, which are major tributaries of the river Ganga. The Takoligad (stream) originates from the Eastern slope of the Chandrabadni Peak (2301 meter) and joins the Alaknanda river at Jayal Garh (550 meter).

Material and Methods

The study was carried out during the August 2006 to July 2007. The whole study area was divided into three altitudinal zones: Lower (500-1000 m asl), Middle (1000-1500 m asl), and Higher (1500-2000 m asl). 5 villages were identified along each altitudinal zone and

10 household from each village, total 150 household were selected for this study. A detailed study plan was carried out on the resource use pattern and choice of species for fuelwood by the local people. Structured and semi-structured questionnaires were used and the identification of major fuelwood species was based on interviews, informal individual/group discussions and direct observations (Martin, 1995). From each altitude, the fuelwood species were identified with the help of local people. The local people were asked to name the preferred fuelwood species, gathering time, distance travelled and time taken for their collection. In addition, questions were also asked in relation to respondent's perception of the environment and the availability of fuelwood species in the area. A consensus use (CU) value was also calculated for each species cited, taking the number of people who mention a certain species as being used or preferred over the total number of interviewees as the value representing frequency of use or preference of any given species (Ladio and Lozada, 2004). In this way, the effective use of species was recorded separately from their preference, which represented the set of plants considered valuable as fuel. The quantity of fuelwood consumption was estimated over a period of 24 hour using a weight survey method (Bhatt *et al.,* 1994; Mitchell, 1979). The calorific values of the species are based on secondary literature (Kataki and Konwer, 2002; Jain, 1992; Jain, 1998; Krishna and Ramaswamy 1932).

In this study annual rate of deforestation and rate of emission of greenhouse gases per year as a result of burning of fuelwood was also evaluated. The wood volume is expressed in units of cubic meter (m^3), which represents deforestation (m^3) per unit time (World Bank, 1998). Fuelwood biomass data (ton dry mass, t dm) was converted into m^3 by dividing the mass units by an expansion ratio of 1.90 (World Bank, 1998). The emission of total carbon is estimated by multiplying the quantity of biomass burnt (t dm) by the fraction of biomass oxidized and the biomass carbon content (t C/t dm) (IPCC, 1994). The default value of 0.9 is used for the fraction of biomass oxidized. For woody biomass, a conversion factor of 0.5 t C/t dm is used. This may be given by the following relation:

$$Ct = Mt \times Mf \quad (1)$$

Where in Equation (1), Ct, Mt and Mf represent total biomass burnt (t dm), fraction of biomass oxidized (0.9) and woody biomass carbon content (0.5 t C/t dm) respectively. The emission of CO_2 from fuelwood burning can be estimated by conversion of total carbon content (t C) to Carbon dioxide content (t CO_2) using the conversion ratio of 44 t CO_2/12 t C. This is explained in the following equation (IPCC, 1994):

$$CO_2 = Mt \times Mf \times Mc \times (44/12) \quad (2)$$

Where in Equation (2), CO_2 = Total CO_2 (t CO_2) released from the fuelwood burning, Mt = Total biomass burnt (t dm), Mf = Fraction of biomass oxidized (0.9), Mc =Biomass carbon content (0.5tC/t dm).

Non-CO_2 gases emission including CO, CH_4, NO, N_2O, NOX owing to burning of biomass (fuelwood) was estimated using the following relations (Delmas, 1993; World Bank, 1998).

1) CO emissions (t CO) = Carbon released (t C) × Emission ratio (0.060) × (28/12).
2) CH_4 emissions (t CH_4) = Carbon released (t C) × Emission ratio (0.012) × (16/12).
3) NO emissions (t NO) = Carbon released (t C) × Emission ratio (0.121) × N/C ratio (0.01) × (30/14).
4) N_2O emissions (t N_2O) = Carbon released (t C) × Emission ratio (0.007) × N/C ratio (0.01) × (44/28).
5) NOX emissions (t NOX) = Carbon released (t C) × Emission ratio (0.121) × N/C ratio (0.01) × (46/14).

Results and Discussion

Socio- economic characteristics of household

The descriptive statistics of household attributes which directly or indirectly govern the quality of life of the people of Takoligad watershed, together with health and fuelwood dependency parameters, are summarized in Table 1. In the watershed families were in general found to be extended families, with a maximum of 15 members and an average of 5.14 members. The primary source of income for 60% local people was agriculture and animal husbandry. Monthly income of respondent households varied from Rs 800 to Rs 30,000 while average monthly expenditure was Rs 3064.7. Most of houses were found to be constructed of pakka (brick and cement 53%), the

Table 1 Demographics and cooking energy parameters of sample households

Parameter	Mean ± SE	Minimum	Maximum
Family size (persons)	5.14 ± 2.62	1	15
Total land area (ha)	0.36 ± 0.34	0.03	1.7
Income per household per month (Rs)	6367.3±1243.1	800	30000
Expenditure per household per month (Rs)	3064.7±1738.13	500	10500
Distance of household from road (km)	2.07 ± 0.19	0	5
Distance of household from forest (km)	0.88±0.57	0.5	2.5
Amount of fuelwood consumption per day (Kg)	9.4 ± 1.59	7.97	11.12
Distance traveled for fuelwood collection (km)	2.10± 0.18	1	4
Time spent for fuelwood collection (hrs)	3.15 ± 0.21	1	6

remaining being katcha (mud, stone and wood 26%) and katcha/pakka both (some part katcha & some part pakka 21 %). Landholding size varied from 0.03 to 1.7 ha with an average of 0.36 ha but with almost 80% of the landholdings being 0.5 ha or smaller. The area of irrigated land averaged only 0.001 ha per household, mainly due to lack of irrigation facilities and hilly terrain. About 32% of households were engaged in labouring work, 9% were artisans and 35% were salaried employees.

Preferred fuelwood species and their availability in the watershed

On the completion of the field work that included personal interview, discussions with villagers and personal observation, a total of 10 trees and 4 shrub species were identified as the preferred fuelwood species. These 14 woody species are *Alnus nepalensis, Holmskioldia sanguine, Indigofera heterantha, Lyonia ovalifolia, Pinus roxburghii, Quercus floribunda, Woodfordia fructicosa, Rhus purviflora, Shorea rebersa, Mallotus philippensis, Toona ciliata, Q. Leucotrichophora, Q. semecarpifolia* and *Rhododendron arboretum.* These preferred fuelwood species possessed good fuel characteristics like high calorific value, burn well with good and gradual flame, and produce less smoke. People also use many other agro-forestry species as fuelwood but they preferred to use these species more likely as fodder viz. Kharik (*Ciltis australis),* Bhimal *(Grewia optiva),* Dainkan *(Melia azedarach)* etc.

Maximum number of fuelwood species 9 were used in the Higher altitude (1500-2000 m asl) followed by 6 species in Middle (1000-1500 m asl) and 5 species in Lower (500-1000 m asl). *Quercus floribunda, Alnus neplensis, Rhododendron arboreum, Lyonia avolofolia, Pinus roxburghii* etc. were exclusively used in Higher altitude (1500-2000 m asl) while *Quercus floribunda*, *Rhododendron arboretum, Alnus neplensis, Shorea rebersa, Pinus roxburghii* and *Indigofera heterantha* were preferred species in Middle altitude (1000 – 1500 m asl). *Pinus roxburghii, Rhus purviflora, Mallotus philippensis, toona ciliata, Woodfordia fructicosa* Lower altitude (500-1000 m asl). *Pinus roxburghii* was commonly used in all three altitudes. Details of preferred fuelwood species in three different altitudinal zones have been compiled in table 2.

Table 2 Preferred fuelwood species and their ecological status in different altitudinal zones

Altitudes	Preferred firewood species (Scientific Name)	Vernacular Name	Family	Category	Ranking (fuelwood quality)	Uses	Calorific value (KJ/g dry weight)
Lower (500-1000 m asl)	*Pinus roxburghii*	Chir	Pinaceae	Tree	1	Fuelwood, timber	23.17
	Rhus purviflora	Tungla	Anacardiaceae	Shrub	3	Fuelwood	-
	Mallotus philippensis	Ruina	Euphorbiaceae	Tree	4	Fuelwood, fodder	-
	Toona ciliate	Tun	Meliaceae	Tree	2	Fuelwood, fodder, timber	-
	Woodfordia fructicosa	Daula	Lythraceae	Tree	5	Fuelwood, fodder	-
Middle (1000-1500 m asl)	*Alnus nepalensis*	Utees	Betulaceae	Tree	3	Fuelwood, fodder, timber	15.29
	Shorea rebersa	Sal	Dipterocarpaceae	Tree	4	Fuelwood, timber	-
	Indigofera heterantha	Sakinjo	Fabaceae	Shrub	5	Fuelwood, fodder	-
	Quercus floribunda	Moru	Fagaceae	Tree	1	Fuelwood, timber	22.92
	Rhododendron arboretum	Burans	Ericaceae	Tree	2	Fuelwood, fodder	21.54
	Pinus roxburghii	Chir	Pinaceae	Tree	6	Fuelwood, timber	23.17
Higher (1500-2000m asl)	*Alnus nepalensis*	Utees	Betulaceae	Tree	2	Fuelwood, fodder, timber	15.29
	Quercus semecarpifolia	Kharsu	Fagaceae	Tree	8	Fuelwood, fodder	23.82
	Quercus leucotrichophora	Banj	Fagaceae	Tree	7	Fuelwood, fodder	24.0
	Holmskioldia sanguinea	Khagsoo	Verbinaceae	Shrub	9	Fuelwood, fodder	-
	Indigofera heterantha	Sakinjo	Fabaceae	Shrub	6	Fuelwood, fodder	-
	Lyonia ovalifolia	Aiyangyaar	Ericaceae	Tree	4	Fuelwood, fodder	18.05
	Pinus roxburghii	Chir	Pinaceae	Tree	5	Fuelwood, timber	23.17
	Quercus floribunda	Moru	Fagaceae	Tree	1	Fuelwood, timber	22.92
	Rhododendron arboreum	Bhurans	Ericaceae	Tree	3	Fuelwood, fodder	21.54

According to respondents, each day they travel a long distances (1-5 Km.) to collect the referred fuelwood species and spent large part of day ranging from few hours to half a day to collect fuelwood, which is an evidence of increasing scarcity of fuel species in the region. However, the maximum fuelwood is collected during winter season (October to March) when demand of domestic energy peaks while demand for agricultural labour is relatively low. High dependency on fuelwood was associated with free access to forests, poverty, irregularity of employment, and unavailability or un-affordability of alternative fuel. In near future the availability of these preferred fuelwood species would become difficult and at that point of time these people would have no option other than utilising whatever will be available to them.

Villagers of lower altitude (500-1000 m asl) travel more distance and spent more time in search of preferred fuelwood species as compared to higher and middle altitudes. The main reason is that the availability of preferred fuelwood species is low in the lower altitudes and population is high as compared to the high altitudes. At lower altitudes villagers mostly used agroforestry plant species for fuelwood and fodder. Fuelwood collection is carried out mainly by women and childrens, but sometimes men also take part in the exercise. The sickle (*Daranti*) and rope are the main tools used in the fuelwood collection. Villagers make rope with the fiber of Bhimal (*Grewia optiva)* and Bhimal also used by some elderly women's as shampoo for washing their hairs. The time dedicated to searching and collecting fuelwood was not quantitatively analyzed, but was qualitatively evaluated based on the informants' comments (personal communication). Both attached (dead but still standing) and detached (fallen on ground) deadwood was also collected in addition to cutting the live trees. Some people prefer to cut and collect all parts of trees available in the nearby areas rather than spending time in searching dry wood and woody shrub. The *villagers* make the heap of collected sapwood and leave it for drying and use it during demand of agriculture labour is high and there are no time to collect dry wood from forest.

Altitudinal and Seasonal variations in fuelwood consumption

At Lower altitude (500-1000 m asl), the total annual fuelwood consumption was estimated to be 8723.5 Kgs (2401.7 during summer, 3942 during winter, 2379.8 kgs during monsoon). Fuelwood consumption (kg/household/day) varied from one household to another which was depending on size of the family. All the 5 *villages* at this altitudinal gradient, maximum fuelwood consumed during winter season which was on an average 10.80 ± 3.09 kg/household/day, while in summer and monsoon season consumed fuelwood was estimated 6.58±2.93 kg/household/day and 6.52 ± 3.15 kg/household/day (Table 3 and Fig. 2). Fuelwood consumption was maximum during winter in all the villages but not very much difference between summer and monsoon consumption.

At Middle altitude (1000-1500 m asl), the total fuelwood consumption of all the 5 *villages* was estimated to be 9979.1 kgs/year (2679.1 during summer, 4642.8 during winter and 2657.2 during monsoon). Out of 3 seasons, maximum fuelwood was consumed during winter at the rate of 12.72±3.01 kgs/day, while in summer and monsoon at the rate of 7.34 ± 2.48 and 7.28±3.01 kgs/day (Table 3 and Fig. 2). There was a little difference between the summer and monsoon fuelwood consumption, it was just 0.06 kg/day.

At Higher zone (1500-2000 m asl), which is higher altitudinal site of the watershed the total fuelwood consumption was estimated to be 12176.4 kgs (3525.9 during summer, 5263.3 during winter and 3387.2 during monsoon). Maximum fuelwood was consumed during winter at the rate of 14.42±3.69 kgs/day, while in summer and monsoon at the rate of 9.66 ± 3.03 and 9.28±2.93 kgs/day (Table 3 and Fig. 2).

Although; it is observed that maximum fuelwood consumption in all three altitudinal zones in winter season and high altitudinal villagers consume more fuelwood than other two altitudes in winter. It may be due to close vicinity of forest and also not easy accessibility of alternative energy sources.

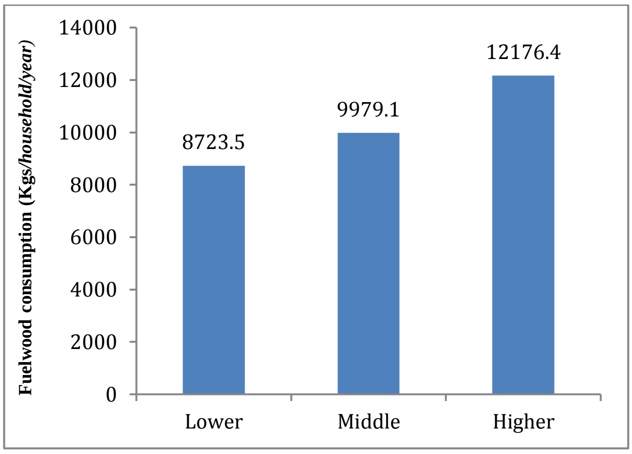

Figure 2: Annual average fuelwood consumption in different altitudinal zones

In the present study it has been found that fuelwood is an essential resource for villagers. An increased demand of biomass for consumptive use of rural communities has considerable impact on the forest vegetation and wildlife (Chettri *et al.,* 2002). Fuelwood is locally available and free in Garhwal Himalaya, whereas commercial fuels are either not available or are too expensive for poor villagers (Bhatt and Badoni, 1990). In Garhwal Himalaya, the only cost of fuelwood collection is physical efforts and the time taken (Singh *et al.*, 2010). The present study showed that fuelwood consumption at different altitudes by *villagers* ranged from 1.50 to 2.46 kg/capita/day while at household

Table 3 Fuelwood consumption in three altitudinal gradient

Altitudes	Fuelwood consumption /household/ Day (kgs)	Annual fuelwood consumption/ household (kgs)
Lower (500-1000 m asl)		
Summer	6.58±2.93	2401.7
Winter	10.80±3.09	3942.0
Monsoon	6.52±3.15	2379.8
Total Consumption		8723.5 kgs
Middle (1000 – 1500 m asl)		
Summer	7.34±2.48	2679.1
Winter	12.72±3.01	4642.8
Monsoon	7.28±3.01	2657.2
Total Consumption		9979.1 kgs
Higher (1500 – 2000 m asl)		
Summer	9.66±3.03	3525.9
Winter	14.42±3.69	5263.3
Monsoon	9.28±2.93	3387.2
Total Consumption		12176.4 kgs

level it is 9.40 kg/household/day. The household level consumption is quite less to the consumption level in lower altitudinal areas of Uttarakhand, that is, 13 kg per day (Sati and Song, 2012). Dhyani et al. (2011) reported it to be 35 kg per 2-3 days in Kedarnath Wildlife Sanctuary, Uttarakhand. The values recorded are in the range reported in the Garhwal Himalaya (14.65 kg/household/day) by Awasthi et al., (Awasti, 2003). However, the value are higher than the ones reported for lower altitudinal villages of Western Himalaya (1.49 kg/capita/day) by Bhatt et al., (Stone, 1965), for southern India (1.9–2.2 kg/capita/day) by Reddy (Reddy, 1981), the Himalayan range of Nepal (1.23 kg/capita/day) by Mahat et al., (Mahat *et al.,* 1987) and Himalayan range of Pakistan (2.19-3.76 kg/capita/day) by Shaheen et al., (Shaheen *et al.,* 2011). These authors reported average fuelwood consumption of 20 to 25 kg/household/day.

The fuelwood consumption is higher in high altitudes as compared to middle (Medium) and lower altitudes. The probable reason for the high fuelwood consumption in higher altitude may be that remoteness, poverty, transportation and lower temperature. Villagers depends completely on fuelwood not only for cooking purposes but also for heating place, boiling water and making food concentrate for cattles. Reason for lowest fuelwood consumption in lower altitudinal zone may be to low availability of fuel wood due to population pressure and farthest from the forest.

The very severe impacts of frequent fuelwood harvesting on the structure of the forest is the rapid decline of large old trees resulting in their complete disappearance. Once these trees are lost, the gaps created either by natural tree falls or logging also increase (Ruger *et al.,* 2007) resulting in forest fragmentation and susceptibility to invasion by ephemerals, that inhibit the regeneration of seedlings of native tree species.

Biomass burning and greenhouse gases emissions

Biomass burning is associated with release of greenhouse gases (GHGs). Burning of biomass fuel is responsible for the emissions of both trace and non-trace greenhouse gases, such as CO_2, CH_4, CO, N_2O, NO_X and NO. Combustion of biomass plays a significant role in global atmospheric chemistry due to the non-CO_2 trace gases and its potential for global warming due to an enhanced greenhouse gas effect. However, much of the CO_2 released from the biomass burning does not result in a net increase in atmospheric concentration because the plants absorb it during photosynthesis. The accurate estimation of greenhouse gas emission from biomass fuel burning in small combustion at local level is important to know their significance and to suggest suitable mitigation options.

The study revealed that the total annual quantity of fuelwood consumed by the watershed communities at different altitudes was 3320.05 t dm. As a result, the estimated total deforestation was 1747.40 m^3 in the watershed. Due to combustion of this fuelwood the emission of different gases was 1494.02 t Carbon, 5478.09 t CO_2, 209.16 t CO, 23.90 t CH_4, 0.16 t N_2O, 5.94 t NO_X and 3.87 t NO (Table 4). Continued destruction of forestation will impact the lives of villagers primarily by raising the time it takes them to collect fuelwood. If trees are more severely lopped, the villagers will take longer to collect a single bundle, either by searching longer for trees. This is the principal source of the local externality: higher collections today by any single household will raise collection times for all households in surrounding villages in the future. To the extent that policy interventions are deemed desirable to limit fuelwood collections, it is natural for economists to think of corrective taxes and subsidies on LPG and other alternative energy sources.

The fragile Himalayan environment is suffering from slow but consistent deforestation and soil erosion, which is threatening the regions biodiversity. The use of fuelwood as a primary source of energy for

Table 4 Computed amount of GHGs release in the atmosphere

Parameter	Value
fuelwood consumption/year (t dm)	3320.05
Potential deforested wood (cubic metre)	1747.40
Green house gas emissions	
Carbon content in biomass (t C t dm)	1660.03
Carbon released (t C)	1494.02
Carbon dioxide emission from burning (t CO_2)	5478.09
Non-CO_2 emissions	
CO emissions (t CO)	209.16
CH_4 emissions (t CH_4)	23.90
NO emissions (t NO)	3.87
N_2O emissions(t N_2O)	0.16
NOx emissions (t NOx)	5.94

domestic and commercial use is a cause of severe deforestation in Himalaya. The use diversity of fuelwood species depends on the wood quality, accessibility, availability and also the human population in the surrounding villages (Singh *et al.*, 1988). Deforestation not only makes life difficult of villagers as they use forest product for their energy requirement but also contribute significantly in the emission of greenhouse gases. Three quarters of the western Himalayan forest cover have been lost in last century (Joshi *et al.,* 2001). Eight (8%) percent loss in the Eastern and 23% in the western Himalayas have occurred in last three decades (Anonymous, 2005). It has been reported that tree felling for fuelwood accounts for the largest share of wood use in developing countries causing rapid deforestation (Kataki and Konwer, 2002). The consumption of fuelwood has a complex interrelationship with deforestation (Heltberg *et al.,* 2000; Rudel, 2005). Communities living in the Himalayas have developed an age old tradition of selectively using a wide variety of forest resources for fuelwood based on their quality and availability (Rai *et al.,* 2002). Many of the preferred and higher quality species are under pressure, leading to changes in species compositions and forest succession patterns (Chettri *et al.,* 2002).

The release of GHGs due to combustion of fuelwood appears to be very small; however, it has cumulative effect on total GHGs and climate change in future. The potential solution of this problem could be: a) Sustainable harvesting of fuel wood for reducing the pressure on forests and allowing trees and forests to regenerate and act as stronger carbon sinks; and b) Plantation of fuelwood species with higher calorific value in wasteland and fallowlands.

Conclusion

In this study it is observed that rural household depends on forest for their energy requirement. This is so because the rural households are resource constrained and availability of other cheaper alternatives to fuelwood is poor. This situation creates an additional pressure on the forest. Sustainable utilisation of forest and associated land resources is a complex issue that encompasses societal needs, ethical and cultural values, and economic status of communities. Fuelwood is renewable and its consumption can only be sustained if the rate of harvesting does not exceed the growth rate. Irrational use of natural resources has resulted in the lowering of forest quality and shortage of resources especially preferred firewood species. Excessive harvesting increases the deforestation rate. Consumption is the most important variable in defining the potential contribution of a wood fuel source and also in assessing the risk of its degradation or overexploitation. Higher fuel wood consumption in the study area is mainly due to lack of accessibility of alternative energy sources, remoteness and poverty. Extensive farming for fuelwood could be the alternative to bridge the gap between the demand and supply and hence, efforts are needed for mass afforestation of suitable fuelwood species in the barren/wasteland areas around the

Takoligad watershed and this will immensely help in reducing the degradation of forests. Conservation of these forests would not be possible without the active participation of the local people. Establishment and empowerment of Van Panchayats also contribute in forest management and sustainable use of forest resources. The local people are allowed to collect twigs and branches from the forest floor and also some extent to extract dry branches of fuelwood and carry on head loads for domestic consumption by permission of the Van Panchayats. By improving their living standards and by giving benefits of conservation to them, long term conservation goals can be achieved. Though, energy development and utilisation should be placed in a sustainable development context to ensure that no dimensions, resource or policy tools are overlooked (Kaygusuz, 2012) and countries like India with diverse agro-climatic zones need to have local specific energy policy.

References

Anonymous (1991). Census data of Garhwal region of Uttar Pradesh.

Anonymous (2005). FSI (Forest Survey of India). The State of Forest Report 2003. Dehradun, FSI, Ministry of Environment and Forests, Government of India.

Awasti A, Uniyal SK, Rawat GS, Rajvanshi A (2003). Forest resource availability and its use by the migratory villages of Uttarkashi, Garhwal Himalaya (India). Forest Ecology and Management 174: 13–24.

Bhatt AK, Badoni AK (1990). Fuel characteristics of some mountain firewood shrubs and trees. Energy 15: 1069-70.

Bhatt BP, Todaria NP (1990). Fuel wood characteristics of some mountain trees and shrubs. Biomass 21:233- 38.

Bhatt BP, Negi AK, Todaria NP (1994). Fuelwood consumption pattern at different altitudes in Garhwal Himalaya. Energy 19 (4), 465–8.

Bhatt BP, Sachan MS (2004). Firewood consumption along an altitudinal gradient in mountain villages of India. Biomass Bioenergy 27: 69–75.

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

Campbell JG, Bhattarai TN (1984). People and forests in hill Nepal. Preliminary presentation of findings of community forestry household and ward leader survey; Project paper 10, HMG/UNDP/FAO community forestry development project, Nepal.

Chettri N, Sharma E, Deb DC, Sundriyal RC (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): 150-8.

Dahdouh-Guebas F, Mathenge C, Kairo JG, Koedam N (2000). Utilization of mangrove wood products around

Mida Creek (Kenya) amongst subsistence and commercial users. Economic Botany 54: 513-27.

Delmas R (1993). An overview of present knowledge on methane emission from biomass burning.

Amersfoort, The Netherlands. RIVM Report No 481507003. In: van Amstel, A.R. (Ed.), Proceedings of an International IPCC Workshop : Methane and Nitrous Oxides, Methods in National Emissions Inventories and Options for Control. Bilthoven, The Netherlands; P.3-5.

FAO (2007). A review of the current state of bioenergy development in G8 þ5 countries (/www.fao.orgS).

Heltberg R, Arndt TC, Sekhar NU (2000). Fuelwood consumption and forest degradation: a household model for domestic energy substitution in rural India. Land Economics 76:213-32

IPCC (1994). IPCC Guidelines for National Greenhouse Gas Inventories, vols. I, II and III. Intergovernmental Panel on Climate Change, United Nations Environment Program, World Meteorological Organization, Organization for Economic Co-operation and Development and International Energy Agency.

Jain RK (1992). Fuelwood characteristics of certain hardwood and softwood tree species of India. Bioresource Technology 41(2):129–33.

Jain RK (1998). Fuelwood characteristics of some trees of India. Indian Journal of Forestry 14:155–9.

Joshi PK, Singh S, Agarwal S, Roy PS (2001). Forest cover assessment in western Himalayas, Himachal

Pradesh using IRS 1C/1D WiFS data. Current Science 80: 941-7.

Kataki R, Konwer D (2002). Fuelwood characteristics of indigenous tree species of north-east India. Biomass Bioenergy; 22(6): 433-7.

Kaygusuz K (2012). Energy for sustainable development: a case of developing countries. Renew Sustain Energy Reviews 16:1116–26.

Krishna S, Ramaswamy S (1932). Calorific Values of Some Indian Woods Indian Forest Bulletin (N.S.) No 79. Chemistry. Calcutta, India: Central Publication Branch, Government of India.

Kumar P (2005). Natural Resource Policy: Some Related Issues. In: Dewan ML, Bahadur J, editors. Uttaranchal Vision and Action Programme: Concept Publishing Company; New Delhi.

Ladio AH, Lozada M (2004). Patterns of use and knowledge of wild edible plants in distinct ecological environments: a case study of a Mapuche community from northwestern Patagonia. Biodiversity Conservation 13(6):1153-73.

Mahat TBS, Grigffin DM, Shepherd KP (1987). Human impact on some forest of the middle hills of Nepal. Part 4: A detailed study in Southeast Sindhu Palanchock and Northeast Kabhere Palanchock. Mountain Research and Development 7: 114–34.

Martin GJ (1995). Ethnobotany—a methods manual. London: Earthscan Publishers Ltd.; p. 268.

Metz JJ (1990). Conservation practices at upper elevation village of west Nepal. Mountain Research and Development 10 (4):7–15.

Medeiros P, Santos de Almeida AL, Da Silva TC, Albuquerque UP (2011). Pressure indicators of wood resource use in an Atlantic forest area, northeastern Brazil. Environmental Management 47: 410-24.

Mitchell R (1979). An analysis of Indian agroecosystem. New Delhi, India: Interprint.

Natarajan I (1985). Domestic fuel survey with special reference to kerosene, I. New Delhi: National Council for Applied Economic Research.

Nirmal Kumar JI, Rita NK, Rohit KB, Sajish PR (2009). Quantification of nutrient content in the above ground biomass of teak plantation in tropical dry deciduous forest of Udaipur, India. Journal of Forest Science 55(6):251e6.

Osei WY (1993). Wood fuel and deforestation-answers for a sustainable environment. Journal of Environmental Management 37:51–62.

Rai YK, Chettri N, Sharma E (2002). Fuelwood value index of woody tree species from forests of Mamlay Watershed, South Sikkim, India. Forests Trees Livelihoods 12: 209–19.

Reddy AKN (1981). An Indian village agricultural ecosystem case study of Ungra village. Part II. Discussion. Biomass 1: 77–88.

Rudel TK (2005). Tropical Forests: Regional Paths of Destruction and Regeneration in the Late 20th Century. New York: Columbia University Press.

Ruger N, Gutierrez AG, Kissling WD, Armesto JJ, Huth A (2007). Ecological impacts of different harvesting scenarios for temperate evergreen rain forest in southern Chile – a simulation experiment. Forest Ecology and Management 252: 52-66.

Sati VP, Song C (2012). Estimation of forest biomass flow in the Montane Mainland of the Uttarakhand Himalaya. International Journal of Forest, Soil and Erosion, 2(1): 1-7.

Sharma A, Prasad R, Saksena S, Joshi V (1999). Micro level sustainable biomass system development in central Himalaya: stress computation and biomass planning. Sustainable Development 7(3):132–9.

Shaheen H, Qureshi RA, Ullah Z, Ahmad T (2011). Anthropogenic pressures on the Western Himalayan moist temperate forests of Bagh, Azad Jammu & Kashmir. Pakistan Journal of Botany 43(1): 695-703.

Singh, J.S., Singh, S.P., Pam, J. (1988). Fodder and Fuelwood resources of Central Himalaya: problems and solutions. Project report, Planning commission, GOI, New Delhi, pp. 159.

Singh, G., Rawat, G.S., Verma, D (2010). Comparative study of fuelwood consumption by villagers and seasonal ''Dhaba owners'' in the tourist affected regions of Garhwal Himalaya, India. Energy Policy 38 (2010) 1895–1899.

Stone EC (1965). Preserving vegetation in parks and wilderness. Science 150: 1261-7.

Sundriyal RC, Sharma E (1996). Anthropogenic pressure on tree structure and biomass in the temperate forest of Mamlay Watershed in Sikkim. Forest Ecology Management 81: 113–34.

Vasudevan P, Santosh (1987). The role of women in energy related activities in the mountains. In: Kumar V, Ahuja D, editors. Rural energy planning for the Indian Himalaya. New Delhi: Wiley.

Wahab M, Ahmed M, Khan, N (2008). Phytosociology and dynamics of some pine forests of Afghanistan, Pakistan Journal of Botany 40(3): 1071-9.

Walters, B.B. (2005). Patterns of local wood use and cutting of Philippine mangrove forests. Economic Botany 59, 66-76.

World Bank (1998). Greenhouse Gas Assessment Handbook: a Practical Guidance Document for the Assessment of Project-level Greenhouse Gas Emissions. USA: Global Environment Division, the World Bank, USA.