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ORIGINAL ARTICLE

Fuelwood consumption patterns by semi-nomadic pastoralist community and its implication on conservation of Corbett Tiger Reserve, India

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Abstract The local folk of Himalaya have natural coexistence with the forests and depend on these bounty natural resources for their livelihood. The present study was carried out on semi-nomadic pastoralist for the study of forest use patterns. The main source of livelihood was found to be homogeneous (pastoralism) within each settlement. The study records 26 tree species preferred for fuelwood consumption. Overall average fuelwood consumption was 20.09 ± 0.7 kg day^{-1} family^{-1}. The average per capita fuelwood consumption was 2.77 kg day^{-1}. Average fuelwood consumption by very large families is significantly higher than small families. The principal component analysis explain lopping, extraction and anthropogenic activities for biomass extraction as a major factor of disturbance in forests. We also examined the present forest wood consumption rate and its implications in terms of potential deforestation and emission of greenhouse gases. The findings in the paper could form the basis for designing appropriate technologies and management policies in the region.

Keywords Van Gujjars · Settlements · Fuelwood consumption · Species preference · Fuelwood sources · Principle component analysis

1 Introduction

The term biomass encompasses all energy forms derived from organic fuels of biological origins. Biomass accounts for approximately 14% of total energy used globally and it is the largest energy source for the three-quarters of the world's population who live in developing countries (Günhan et al. 2005). In India, rural households depend to a large extent on locally available resources collected from the forests to meet their domestic energy needs. Firewood is the most attractive among the various forms of biomass and occupies a predominant place in the rural energy budget (Kataki and Konwer 2002). The people of the Himalayan region have been fulfilling their energy needs almost entirely from forests (Bhatt and Sachan 2004). Fuel wood has been identified as one of the most significant causes of forest decline in many developing countries (Malik et al. 2014). Firewood accounts for over 54% of all global harvests per annum, suggesting a significant forest loss (Osei 1993; Wahab et al. 2008). The intense use of forest resource has put woody species in different regions of the world at risk (Dahdouh-Guebas et al. 2000; Medeiros et al. 2011; Walters 2005). In various studies, it has been found that countries with large rural populations make greater use of wood for heat and cooking fuel (Miah et al. 2003; Moran-Taylor and Taylor 2010; Ogunkunle and Oladele 2004). Bio-energy 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). This scenario calls for proper biomass planning, especially in the Himalaya, as almost 90% energy demand is met with biomass resources (Sharma et al. 2009).

On the other hand without access to modern energy resources, communities are dependent on traditional biomass such as fuelwood, charcoal and animal waste for cooking and heating (Kaygusuz 2011). Due to low

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connectivity with the urban areas of the country, poor socio-economic conditions, sky-rocketing prices and limited supply, the commercial energy component formed only 1.41% of the total, comprising of kerosene and electricity (Bhatt and Sachan 2004; Kumar 2005). The rapid growth of population as well as decreasing forest areas have led to depletion of fuelwood resources around localities, causing fuelwood shortage which has a direct impact on the poor, such as extending fuelwood collection time, increasing fuelwood prices, and putting into risk a basic human need (International Energy Agency 2006; Arnold et al. 2006).

According to Kanagawa and Nakata (2007), fuelwood consumption not only increase the direct payments of rural households, but valuable time and effort is devoted to fuelwood collection, resulting in loss of the opportunity for collectors to improve their education and engage in income-generating activities. Unsustainable fuelwood collection and inefficient conversion technology have serious implications for the environment (Arnold et al. 2003; Chen et al. 2006). Burning fuelwood produces large amounts of carbon dioxide (CO_2), but the emissions from fuelwood consumption are considered as carbon neutral if fuelwood is harvested sustainably. Due to incomplete and inefficient combustion, fuelwood use may not be carbon neutral because carbon is released in other forms, including methane, nitrous oxide, carbon monoxide and non-methane hydrocarbons, which have more global warming potential (GWP) than CO_2 (Smith et al. 2000). In Asia, for instance, production of these incompletely combusted gases account for 4.5% of total biomass fuel carbon emissions, which are equivalent to 23% of CO_2 emissions on a 20-year global warming potential basis (Lefevre et al. 1997).

Various studies had been conducted by different authors on the fuelwood consumption pattern in the Himalayan region on migratory villages in Uttarkashi district (Awasti et al. 2003), along altitudinal gradients in Garhwal Himalaya (Bhatt and Sachan 2004), Northeast India (Bhatt and Sachan 2004), Pindar basin (Sati 2008), Himachal Pradesh (Prasad et al. 2001; Sharma et al. 2008) and Tehri district in Uttaranchal (Negi et al. 1999). The issue as such has been addressed invariably, but there has been almost no attempt to analyse the fuelwood consumption by semi-nomadic pastoralist's community *"Van Gujjars"*, unmindful of the resource availability and the possible consequences with particular reference to the Corbett Tiger Reserve (CTR). *Van Gujjars* make extensive collection of fuelwood for cooking purposes. Therefore, the present work focuses on the socio-economic conditions, utilization patterns of fuelwood species, consumption and usage patterns and preference of woody species (trees and shrubs) and so on. We examined the occurrence of regionally specific ecological indicators that encompassed several aspects of human activities. In addition, we evaluated the annual rate of deforestation and evaluated the rate of emission of green house gases as result of burning of firewood.

2 Materials and methods

2.1 Site description

The study was conducted in *Van Gujjar* settlements (*Khatta's*) located in and around the CTR, Uttarakhand, India (Table 1). The CTR is situated at the foothills of the Western Himalayas in the civil district of Nanital and Pauri Garhwal in Uttarakhand, India. The area of CTR extends from 78°39′40″E to 79°09′23″E longitude and 29°48′N to 29°23′32″N latitude. The area of the CTR is 1288.32 km^2. The altitude of CTR ranges between 385 and 1100 m asl. The park receives about 1500 mm to 1600 mm of rainfall mainly during the monsoon though some winter rain always occurs. The temperature ranges between 4 °C in winter to 42 °C during the summer season. The park represents the amalgamation of culture in western Himalayan foothills, and displays amazing landscapes and diverse flora and fauna. The vegetation consists mostly of dry and moist deciduous forests dominated by Sal (*Shorea robusta*), scrub savannah and alluvial grasslands.

2.2 Semi-nomadic pastoral community (Van Gujjars)

The *Van Gujjars* ("*Van*" meaning "forest" in Hindi) live in the lower sub-Himalayan parts of Uttarakhand State and are one of the most important migratory tribes of the Himalayas. The *Van Gujjars* follow Islamic religion and have their distinct culture and traditions (Hussain et al. 2016a, b). Their main occupation is herding goats, sheep and buffaloes as the primary source of income. They live in close proximity to forest environment along with their herds inside the forest area. The members stay around the CTR in traditional huts, which are locally known as *deras*, which are built from the forest material such as wood, bamboo and grass for thatching purposes and the making of roofs over clearings in the forest (Hussain et al. 2014). Most of the families are isolated from urban centres (Hussain et al. 2012).

2.3 Data collection and analysis

An extensive field survey was carried out to study the fuelwood consumption pattern among the selected community. In order to carry out survey permission was first taken and research project was explained to local authorities and residents. A preliminary survey was conducted

Table 1 Location of *Van Gujjar's* settlements in and around CTR

Name of settlement	Geo-coordinates	No. of settlements	Population
44 No. Shivnath-pur Khatta	N29°21′49.2″ E078°58′26.9″	9	53
Aamphokra 64-Gate	N29°19′22.7″ E079°01′28.5″	13	80
Arjun Naala Khatta	N29°17′24.8″ E079°04′51.7″	26	189
Balli Gate Khatta	N29°15′18.8″ E079°10′12.9″	2	20
Basiowalakhata	N29°15′54.6″ E079°10′31.4″	5	30
Baudlisaut	N29°43′22.9″E078°45′32.4″	1	13
Beelghati	N29°22′39.4″ E079°01′13.6″	10	63
Bitarnala	–	4	22
Chandni Choi	N29°21′21.4″ E079°09′07.1″	2	16
Deela Barrage	N29°20′58.3″ E079°01′09.8″	8	61
Della Goan	N29°24′52.9″ E079°00′05.5″	8	41
Gallikaithani	N29°15′17.9″ E079°11′27.0″	14	88
Gaudlisaut	N29°44′17.3″ E078°43′58.4″	4	27
Gojara	N29°37′14.0″ E078°58′09.7″	14	107
Gullar Gati	N29°22′59.4″ E078°54′02.6″	19	124
Haldgadi	N29°41′07.7″ E078°47′32.8″	2	18
Hathi Dangar	N29°21′30.4″ E079°01′17.2″	9	62
Jawalavan	N29°17′17.4″ E079°07′23.4″	6	41
Kalusaud	N29°22′19.3″ E078°53′11.5″	6	37
Kamugadar	N29°22′08.5″ E079°00′34.1″	14	106
Kehri Pur	N29°23′11.3″ E078°50′11.4″	3	18
Khansur	N29°42′56.9″ E078°43′36.8″	5	38
Kugada/Kaliatha	N29°45′37.9″ E078°42′40.8″	6	51
Makonia	N29°20′58.8″ E078°48′45.1″	18	150
Maliakhan	N29°40′25.6″ E078°48′40.2″	4	33
Mundyapaani	N29°41′43.8″ E078°46′22.5″	2	20
Murgabhoj	N29°23′43.2″ E078°54′19.2″	4	28
Nabigarh	N29°22′31.1″ E078°52′08.0″	12	86
Nabigarh Theeri	N29°22′59.6″ E078°52′39.0″	26	200
Naunyaganj	N29°17′20.7″ E079°08′23.4″	17	132
Patheliya	N29°13′54.1″ E079°13′35.1″	16	106
Pather Kaun	N29°23′27.2″ E078°55′41.9″	7	50
Phantu	N29°22′48.1″ E078°55′32.0″	6	23
Raninagal	N29°25′25.2″ E078°51′19.8″	10	75
Tomarya Dam	N29°18′16.3″ E078°54′55.8″	16	168
Tomarya Khatta	N29°21′48.2″ E078°58′52.2″	8	51
Vatanvasha	N29°42′04.9″ E078°45′06.4″	4	37

through semi-structured questionnaires. In selected settlements, all the households were surveyed. The heads of respective family were interviewed to determine their socio-economic status in terms of land holdings, income source, number of animals owned and the status of their employment. The families surveyed were chosen to include equal representation from all economic classes and family sizes. The sequence of selection was from households to different family sizes and income groups. The family size was categorized as per the number of individuals in the households as small (1–4), medium (5–7), large (8–10) and very large (>10). The income groups was categorized into five income groups as group 1 (G1): <1 lakh INR; group 2 (G2): 1–2 lakh INR; group 3 (G3): 2–3 lakh INR; group 4 (G4): 3–4 lakh INR; and group 5 (G5): >4 lakh INR. To understand the pressure on individual forest tree species, the respondents were asked to specify their preferences for fuelwood. The identification of major fuelwood species was mainly based on interviews, informal discussions and observations following Martin (1995). The quantity of fuelwood collection was estimated over a period of 24 h using a weight survey method (Mitchell 1979).

Traditionally, the wood lot was weighed and left in the kitchen to be burnt and the actual fuelwood consumption was measured following 24 h. Fuelwood consumption per capita per day was calculated on the basis of total fuelwood consumed by a family, divided by the total number of family members as described by Gupta et al. (1997).The questionnaire used to collect the information was translated into local dialect Gojri and Urdu.

Ecological survey was carried out to quantify the degree of forest disturbance from various livelihood activities according to Karanth et al. (2006). Empirical field data on ecological indicators of forest use and disturbance variables were collected along one hundred twenty-one transects (four transects per settlement) that began at random starting points at the edge of each settlement and radiated outwards in four directions according to Karanth et al. (2006) and Hussain et al. (2012). Each transect was 0.5 km in length, and ecological data were collected at twenty-five sampling points measured 20 m apart. At each point (5×5 m quardat), the following habitat disturbance variables were measured: cut poles, lopped trees, felled trees, fire signs, remnants of branches and leaves, lopped regeneration, cattle presence and clear patch presence. These variables encompass all of the visible signs of disturbance seen around these settlements. For analysis, factor analysis was used to explore the relationship between various disturbance variables. In factor analysis, the factor loadings for the data of various disturbance parameters were extracted using principal components analysis (PCA). Annual rate of deforestation and rate of emission of greenhouse gases per year as a result of burning of fuelwood were evaluated following Tahir et al. (2010).

3 Results

3.1 Socio-economic profile of respondent households

Family size and education status play an important role in planning and proper utilization of fuelwood. Household size ranged from 2 to 18 persons, and average household size was found to be 7.2 members (Table 2). According to family size classes, 18.8% belonged to the small household category, while 12.4% were in the very large category. The overall illiteracy rate was found to be 0%, hence are totally dependent on forests. The main source of livelihood is homogeneous (pastoralism) within each settlement; individual families were dependent on a great variety of different occupations for their livelihood (labour/pastoralism). Majority of respondents (49.7%) indicated pastoralism as their primary source of livelihood. They are also earning their livelihood from combining pastoralism with agriculture (21.2%), pastoralism with daily wage labourers (12.6%) and pastoralism with agriculture and daily wage labour (9.1%). Some people have completely given away their traditional pastoralist nature. They were earning their livelihood from daily wage labour (5.9%), agriculture with daily wage labour (0.9%) and agriculture (0.3%) alone. The average annual income per household varied among the settlements. The lowest average annual income (149644 ± 132331 INR) was found in small households, whereas the highest annual income was estimated to be 453,455 ± 297,437 INR for very large households. The overall annual income was recorded as 78072970 ± 194,286.5 INR (Table 2). There were no clear land rights given to the *Van Gujjar's*. There was no uniform policy deciding the permission of forest department to grow fodder or crops. Depending on the temporary arrangements they manage to grow crops on certain amount of land.

Animal husbandry is an important source of income. Most of the families (95.99%) owned livestock. The total Adult Cattle Unit (ACU) holding in all settlements was about 7574, with average ACU of 23.21 ± 9.48 per household. The livestock are generally dependent on grazing and lopping in adjacent forests, which indicates that forests provide fodder and bedding material for livestock. Majority houses are of traditional type, which are built from forest materials. It was observed that 97.35% of respondents were living in thatched roof with mud wall house, indicating that people do not feel settled in the area, and is indicative of the legal restriction

Table 2 General characteristics of respondent households ($n = 430$)

Family size	Number of families (%)	Occupation			Average annual income		
		Pastoralist	Labour	Pastoralist/ labour	Income from milk	Income from labour	Total income
Small	64 (18.8)	41	3	20	133,877	15,765	149,644 ± 132,331
Medium	123 (36.2)	86	8	29	158,015	15,934	173,820 ± 118,588
Large	111 (32.6)	82	0	29	240,214	12,675	252,890 ± 175,639
Very large	42 (12.4)	27	0	15	434,502	41,571	453,455 ± 297,437

preventing permanent construction. Households cook their food on traditional mud architecture chullahs (stove). The reason behind this large proportion of traditional mud architecture stove users in the area is the easy accessibility of fuelwood and non-availability of any cost effective and readily accessible alternative. Thus, it is evident, that *Van Gujjars* are totally dependent on the adjacent forest divisions for their basic requirements, because they have no clear land rights, jobless, uneducated and low socio-economic status.

3.2 Preferred firewood species and their availability

Fuelwood was the most common and primary source of energy due to its easy availability from the nearby forest, free commodity, low socio-economic status and lack of alternative source of energy. On the completion of survey, 21 tree species were identified as the preferred firewood species. Almost all households reported some plant species preferences for fuelwood use for daily consumption (Table 3). The principal criterion employed by them to determine their preferred species was that species possessed good fuel characteristics such as high calorific value, produces less smoke and also had enough wood hardness. Some of them never select tree species for fuelwood and collect all species which are available in their collection area. This may be the reason, why there is a larger number of tree species used for fuel (Table 3).

Van Gujjars travel considerable distance and spent much time in fuelwood collection. Irrespective of the distance, collection of fuelwood is a necessity for them because there are no alternative sources of energy for cooking and heating. The time devoted to firewood collection was not quantitatively analysed, but was qualitatively evaluated based on personal communication. *Van Gujjars* travel considerable distances (2–4 km) and spent time ranging from a few hours to more than half a day to collect preferred fuelwood. The practice of gathering is related to other tasks performed by residents and is associated with reducing the frequency of trips and performing other important tasks. These walks were conducted mostly by adults, although in some cases by all family members, so both genders had contact with the resource. The dry

Table 3 Preferred firewood plant species used by *Van Gujjars*

Preferred species (scientific name)	Vernacular name	Family	Life form	Availability	CV (kJ g^{-1} dry weight)	Conservation status
Acacia catechu (L.) Willd.	Khair	Mimosaceae	Tree	Moderately	21.97[2]	
Aegle marmelos (L.) Correa	Bel	Rutaceae	Tree	Easily	18.83[2]	
Anogeissus latifolious (Roxb. ex DC.) Wallich ex Richard	Bankli	Combretaceae	Tree	Moderately	21.00[2]	
Casearia elliptica Willd.	Chilla	Salicaceae	Tree	Easily	–	Rare[5]
Cassia fistula L.	Karangal	Caesalpiniaceae	Tree	Easily	21.64[2]	
Cordia dichotoma Forster f.	Lasoda	Ehretiaceae				
Dalbergia sissoo Roxb.	Sissoo	Fabaceae	Tree	Moderately	20.56[2]	
Diospyros choloroxylon Buch.-Ham.	Kinnu	Ebenaceae	Tree	Moderately	21.47[2]	
Ehretia laevis Roxb.	Charnror	Ehritiaceae	Tree	Moderately	16.71[1]	
Haldina cordifolia (Roxb.) Ridsdale	Haldu	Rubiaceae	Tree	Easily	–	
Holarrhena pubescens (Buch.-Ham.)	Kogad	Apocynaceae	Tree	Moderately	–	Least concern[7]
Holoptelea integrifolia (Roxb.) Planchon	Kanju	Ulmaceae	Tree	Easily	22.03[2]	
Lagerstroemia parviflora Roxb., PI. Corom	Dhauri	Lyrthaceae	Tree	Moderately	20.47[2]	
Lannea coromandelica (Houttuyn) Merrill	Kembal	Anacardiaceae	Tree	Moderately	17.14[1]	
Mallotus philippensis (Lam.) Muell.-Arg.	Kamela	Euphorbiaceae	Tree	Easily	20.26[2]	Common[5]
Ougeinia oojeinensis (Roxb.) Hochreutiner	Sandan	Fabaceae	Tree	Moderately	16.93[1]	
Schleichera oleosa (Lour.) Oken	Kumbha	Sapindaceae	Tree	Easily	–	
Shorea robusta Roxb. ex Gaertner f.	Sal	Dipterocarpaceae	Tree	Easily	21.35[2]	Least concern[6]
Terminalia alata Heyne ex Roth	Asin	Combretaceae	Tree	Moderately	21.15[2]	
Terminalia bellirica (Gaertner) Roxb.	Bahera	Combretaceae	Tree	Moderately	20.83[2]	Rare[4]
Toona hexandra (Wallich ex Roxb.) M. Roemer	Tunu	Meliaceae	Tree	Moderately	23.00[3]	

1 = Jain (1992), 2 = Krishna and Ramaswamy (1932), 3 = Jain (1993), 4 = Adhikari et al. (2010), 5 = Sharma et al. (2011), 6 = https://en.wikipedia.org/wiki/Shorea_robusta, 7 = http://indiabiodiversity.org/biodiv/species/show/229948

season was the best season for the gathering of firewood. They store large collections of the gathered fuelwood near their settlements for the winter and monsoon season when the need is greater.

3.3 Energy consumption pattern

In the present study, 100% of families used wood as the main source of energy for cooking and heating purposes, which reflects very high dependency on fuelwood. Fuelwood consumption varied in different household in each settlement. The average fuel wood consumption was recorded as 20.09 ± 0.7 kg day^{-1} family^{-1}, and in terms of average per capita fuel wood consumption, it was about 2.77 kg day^{-1}. The total annual fuelwood consumption was recorded as 2493.169 tonnes. The total numbers of members collecting fuelwood were found to be 443 individuals per day, and average number of members collecting fuelwood per household per day was found to be 1.30 ± 0.0019 members. The percentage of families using other sources of energy for lighting materials was kerosene oil (90.25%) and solar lanterns (64.5%). Average kerosene used (litre/household/month) was found to be 1.45 ± 1.05 L.

3.4 Energy consumption by household size

Fuelwood consumption varied in various family size classes. It was found that maximum numbers of households were in medium-sized families (123 households) and minimum in very large-sized families (42 households). The results reveal that lower average fuelwood consumption (16.12 ± 3.29 kg day^{-1} family^{-1}) was found in small families, while the highest average consumption (26.11 ± 7.00 kg day^{-1} family^{-1}) was found in very large families (Table 4). According to a one-way ANOVA, statistical analysis of fuelwood consumption shows a significant difference between small, medium, large and very large families at the 0.05 level of significance (Table 4).

Based on the household average, average consumption per capita is 1013.69 kg year^{-1} with an average minimum of 718.86 kg year^{-1} in very large families and average maximum of 1735.85 kg year^{-1} in small families. This clearly indicates that fuelwood consumption rates per capita decrease when household size increases. Therefore, households of larger family sizes tend to consume less fuelwood per capita compared with smaller families. Same trend has been followed for the consumption of kerosene per capita with average consumption per capita minimum in very large families (1.48 L year^{-1}) and maximum in small families (4.31 L year^{-1}). The average consumption per capita of kerosene in medium and large families is 2.95 and 2.09 L year^{-1}. This means that larger family households consume fuelwood and kerosene more efficiently than smaller ones.

3.5 Energy consumption by income groups

Energy consumption in different localities and different parts of the country has a variable relationship with socio-economic factors. In this section, five income groups (INR) were formed as group 1 (G1): <1 lakh (86 households); group 2 (G2): 1–2 lakh (105 households); group 3 (G3): 2–3 lakh (70 households); group 4 (G4): 3–4 lakh (36 households); and group 5 (G5): >4 lakh (43 households). It is clear that only a few households were in the groups with higher incomes. The results showed that higher average consumption (22.53 kg day^{-1} family^{-1}) was found in higher income group (G5), while as lower average fuelwood consumption (19.23 kg day^{-1} family^{-1}) was found in the lower income group (G1) (Table 5). It has been found that there is less variation of average fuelwood consumption in different income groups. The less variation may be due to no use of the alternative source of energy for cooking purpose. According to a one-way ANOVA analysis, there is no statistically significant difference in average fuelwood consumption in income groups G1, G2 and G3 ($p > 0.05$). But the average fuelwood consumption of G4 and G5 income groups is significantly different from that of other income groups at the 0.05 level of significance (Table 5). In case of kerosene, the maximum average household consumption was found in higher income group G5 (1.72 L month^{-1}) and minimum in lower income group G1 (1.31 L month^{-1}). The average household kerosene

Table 4 Fuelwood consumption by household size (Mean ± SE)

Household size	Households	Average consumption (kg day^{-1} family^{-1})	Average consumption (MJ/kg day^{-1} family^{-1})	Average consumption (kg family^{-1} year^{-1})	Average consumption (MJ/kg family^{-1} year^{-1})
Small (1–4)	64	16.12 ± 3.297*	317.564	5885.62 ± 1203.56*	115,946.7
Medium (5–7)	123	18.00 ± 2.150*	354.6	6570.0 ± 784.78*	129,429
Large (8–10)	111	22.42 ± 4.590*	441.674	8184.24 ± 1675.20*	161,229.5
Very large (>10)	42	26.12 ± 7.006*	514.564	9533.45 ± 2557.16*	187,809
Total/mean	340	20.09 ± 5.224	395.773	7334.35 ± 1906.9	144,486.7

* The mean difference is significant at the 0.05 level

Table 5 Fuelwood consumption by income groups (Mean ± SE)

Household Income category ($year^{-1}$)	Households	Average consumption ($kg\ day^{-1}\ family^{-1}$)	Average consumption ($MJ/kg\ day^{-1}\ family^{-1}$)	Average consumption ($kg\ family^{-1}\ year^{-1}$)	Average consumption ($MJ/kg\ family^{-1}\ year^{-1}$)
G1: <1 lakh INR	86	19.23 ± 6.13	378.831	7019.88 ± 2238.61	138,291.6
G2: 1–2 lakh INR	105	19.09 ± 4.76	376.073	6966.28 ± 1739.55	137,235.7
G3: 2–3 lakh INR	70	20.07 ± 6.25	395.379	7326.07 ± 2282.65	144,323.6
G4: 3–4 lakh INR	36	22.24 ± 6.71*	438.128	8121.25 ± 2449.85*	159,988.6
G5: >4 lakh INR	43	22.53 ± 6.35*	443.841	8225.23 ± 2319.90*	162,037
Total/mean	340	20.09 ± 5.98	395.773	7335.42 ± 2182.97	144,507.8

* The mean difference is significant at the 0.05 level

Table 6 Standardized loading of various disturbance parameters around settlements

Disturbance parameters	Principal component				
	I	II	III	IV	V
Lopped tree	<u>0.79</u>	0.17	0.04	−0.05	0.05
Remnants of branches and leaves	<u>0.77</u>	0.32	−0.23	−0.08	0.27
Felled trees	−0.01	<u>0.86</u>	−0.24	0.03	0.01
Cut poles	0.24	<u>0.76</u>	0.36	0.11	0.00
Lopped regeneration	0.52	0.61	0.10	−0.18	0.32
Cattle presence	0.09	−0.10	<u>0.78</u>	−0.05	0.08
Clear patch presence	−0.14	−0.01	−0.01	<u>0.94</u>	0.06
Fire presence	0.14	0.09	−0.02	0.05	<u>0.78</u>
Eigenvalues	2.72	2.08	1.70	1.45	1.40
Percentage variance	20.95	16.03	13.09	11.17	10.73
Cumulative explanation	20.95	36.99	50.07	61.25	71.98

Variables underlined with eigenvectors (coefficients) ≥ ±0.70 are considered significant

consumption in G2, G3 and G4 were found to be 1.38, 1.47 and 1.52 L $month^{-1}$ (Table 6).

3.6 Anthropogenic pressure on the forests

The preferred tree species were found to be indiscriminately lopped for fodder and fuelwood extraction. Major forms of anthropogenic disturbances observed in these forests were cut poles, lopped trees, felled trees, fire signs, remnants of branches and leaves, lopped regeneration, cattle presence and clear patch presence (Table 7). The correlation matrix among disturbance variables suggested substantial inter-relationships among many of the measured variables. Because the habitat disturbance variables were all highly correlated with each other, principal component analysis was used to derive a habitat disturbance variables. Eigenvalue analysis suggested that five-principal component be retained as a measure of habitat disturbance. The values of Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy (0.63) and Bartlett's test of sphericity (176.71) suggest that it is significant for analysis. Component matrix of disturbance parameter variables showed that five-principal components were retained as a measure of habitat disturbance which accounted for 71.9% variation. In the principal component I, two (2) disturbance parameters were loaded heavily on component and variables included lopped trees (0.78) followed by remnant of branches and leaves (0.76). This component explains lopping for fuelwood and fodder as a factor of disturbance in the study area. Principal component II shows that two (2) disturbance parameters were loaded heavily on component and disturbance variables included felled trees (0.85) and cut poles (0.76). This component explains extraction of fuelwood as a factor of disturbance in the study area. Principal component III, IV and V shows only one disturbance parameters loaded heavily on each components, and variables included presence of cattle frequency (0.78) followed by presence of clear patch frequency (0.93) and presence of fire sign frequency (0.78). These components explains anthropogenic disturbance for resource extraction as a factor of disturbance in the study area. Principal component coefficients were of relatively similar magnitude for all disturbance variables (only lopped regeneration appeared to be less influential (Table 6). This suggested

Table 7 Ecological status of biotic pressure

Disturbance parameters (25 m^2)	100 m	200 m	300 m	400 m	500 m
Total tree density	1.15	2.25	2.36	1.87	1.72
Felled tree density	0.12	0.24	0.11	0.24	0.15
Lopped tree density	0.85	1.41	1.59	1.13	1.25
Cut pole density	0.12	0.31	0.23	0.31	0.25
Fire frequency	5.33	0.00	1.67	2.33	1.67
Cattle presence frequency	32.00	5.33	1.33	8.00	5.33
Remnants of branches and leaves frequency	40.00	60.00	68.00	69.33	57.33
Clear patch frequency	28.00	0.00	1.33	5.33	1.33
Damaged regeneration frequency	28.00	52.00	53.33	40.00	36.00

that the various manifestations of disturbance around the settlements occurred consistently together. Hence, it is evident from the study, that tree species were indiscriminately lopped for fodder and fuelwood extraction. So, forests in the close proximity of settlements are degrading faster due to biomass extraction.

3.7 Deforestation and greenhouse gases emissions

The fuelwood species due to their easy accessibility and varied utility values were mostly affected due to over exploitation. The respondents mostly use low-efficiency traditional chullahs for cooking purpose. The incomplete combustion of fuelwood in traditional chullah leads to high consumption of fuelwood and may release emission of various green house gasses. The study revealed that the total annual quantity of fuelwood consumed by the *Van Gujjars* was found to be 2493.16 t dm. As a result, the observed total deforested wood was recorded as 1312.19 m^3. Due to combustion of this fuelwood the emission of different gases are given in Table 8.

4 Discussion

In developing countries, the main objective of the establishment of protected areas has been, until recently, to preserve important natural features and unique habitats. In the context of changing human population, socio-economic and environmental conditions, in which rural communities are operating, it is important to develop a method of predicting patterns of fuel wood consumption. In the study area, the mean household size is 7.24 persons per household which is higher than the assessed values for the communities living in the hilly parts of Uttarakhand state and 5.3 persons for the whole country (Census of India 2011). The reason behind their larger families is supported by the fact that large families have an economic impact because of the need for labour for pastoralism. About 98.5% of households admitted that they use fuelwood as source of cooking fuel, that is quite high as compared to 77% reported by NSSO (2007–2008) and recently reported 64% for the whole country (Das and Srinivasan 2012). In *Van Gujjar* community, both genders had contact with the resource. In research studies conducted in other regions, the practice of gathering has shown differences regarding gender (Tabuti et al. 2003; Ramos et al. 2008). All of the households cook their food on *kutcha chulha.* The reason behind this large proportion of *kutcha chulha* users in the area is the easy accessibility of fuelwood and non-availability of any cost effective and readily accessible alternative. Therefore, any strategy for the development of the region necessarily will need to focus to change this situation. The literacy rate and employment of the *Van Gujjars* are very low. Therefore, to alleviate their socio-economic conditions, they should be supported with better educational and employment opportunities (Gaur 2007).

Communities living in the Himalayas have developed an age old tradition of selectively using a wide variety of forest resources for firewood 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). In current study, they preferred 21 tree species for fuelwood purposes. Trees were indiscriminately lopped for fodder and cut down for fuelwood extraction (Hussain et al. 2012). The *Van Gujjars* preference for fuelwood species depends upon the hardness of wood and durability of embers. These criteria coincide

Table 8 Computed amount of GHGs release in the atmosphere

Parameters	Values
Fuelwood consumption/year (t dm)	2493.16
Total deforested wood (m^3)	1312.19
Carbon released (t C)	1121.92
CO_2 (t) emission	4113.72
CH_4 (t) emission	17.95
CO (t) emission	157.06
N_2O (t) emission	0.123
NOX (t) emission	4.460
NO (t) emission	2.90

with research studies which identify the inherent combustion properties of woods, i.e. hardness, heat potential, durability of embers, as recorded for other species in other regions (Chettri et al. 2002; Ramos et al. 2008; Bhatt and Tomar 2002). It would be interesting to conduct combustion analysis on the preferred species, comparing results with the characteristics perceived by residents, thus evaluating traditional ecological knowledge. According to some respondents, selection of tree species for fuel is arbitrary based on the easy availability. This type of selection for fuelwood is also reported by Top et al. (2004) in Cambodia.

The present study showed that fuelwood consumption by *Van Gujjars* ranged from 4 to 36 kg/household/day. The average per capita fuel wood consumption was recorded as 2.77 kg/day. However, the value are higher than the ones reported for southern India (1.9–2.2 kg/capita/day) by Reddy (1981), the Himalayan range of Nepal (1.23 kg/capita/day) by Mahat et al. (1987), for southern and south-eastern Asian countries (1.7–2.5 kg/capita/day) by Dovovan (1981), for Himalayan villages 1.53 kg/capita/day by Bartwal (1987), 1.26–1.95 kg/capita/day by Mishra et al. (1988), 0.76–1.21 kg/capita/day by Saksena et al. (1995) and 1.00–2.72 kg/capita/day by Sharma et al. (2009), Hussain et al. (2013) and, respectively. The earlier researchers as mentioned above reported average fuelwood consumption of 20–25 kg/household/day, while in case of *Van Gujjar,* it was 20.09 kg/household/day. The average fuelwood consumption reported by Awasti et al. (2003) in Garhwal Himalaya was 14.65 kg/household/day. All India average of fuelwood consumption in rural areas as per Centre for Development Finance (CDF) (Source: www.householdenergy.in) comes to be 121.19 kg per month (i.e. 4.06 kg/household/day) which shows that the fuelwood consumption in the study area is quite high. The average energy consumption for all India in rural areas was 79.98 MJ/kg day^{-1} family^{-1}, but the average energy consumption of Van Gujjars was found quite high as 395.77 MJ/kg day^{-1} family^{-1}.

Song et al. (2012), Rosas-Flores and Gálvez (2010), Hussain et al. (2016a, b), Rao and Reddy (2007) indicate that household energy consumption is influenced by several factors, such as income, family size, household land ownership, educational level and local availability. Pachauri et al. (2004) reported that households with low incomes use more non-commercial energy than households with high income level, but this trend was not followed by current study. In current study, it may be concluded that socio-economic condition has no or less effect on fuelwood consumption. The reason may that local communities are totally dependent on forests with no use of alternative source of energy. Other forms of commercial energy are beyond the reach of ordinary people because of poor socio-economic conditions, lack of communication, high prices and limited supply in inaccessible mountain areas (Chettri et al. 2002). This is consistent with the study conducted by Song et al. (2012) in the USA, Rosas-Flores and Gálvez (2010) in Mexico and Miah et al. (2009) in Bangladesh who state that family size has a significant impact on the amount of fuelwood consumption per family. Large families consume more fuelwood both because they have more workers to collect fuelwood and because they have more mouths to feed. Khuman et al. (2011) in Uttarakhand in India report that the household size is inversely proportional to per capita fuelwood consumption at micro level. This interesting reduction in per capita fuelwood consumption with an increase in number of persons in the household has also been observed by Ramachandra et al. (2000) and Hussain et al. (2016a, b). The result of this study is also consistent with the results of research conducted by Top et al. (2003), Hussain et al. (2016a, b), Bhat et al. (2015), Kituyi et al. (2001), Hosier (1985) in Kenya, Marufu et al. (1999) in Zimbabwe, Mahapatra and Mitchell (1999) in India, Kumar and Sharma (2009) in Garhwal Himalaya in India and Kersten et al. (1998) in Nigeria.

5 Conclusion

Deprived socio-economic status and inaccessibility of the area are major factors responsible for the high dependence on nearby forest areas. The findings also reveal that the unavailability of preferred fuelwood species near settlements would force residents to disperse too far and lead to more disturbances of forests. Therefore, option could be to decrease their dependency on the forest by providing alternative sources of energy. Policy should be framed for mass scale afforestation programme of suitable firewood plant species in the less used, barren areas to bridge the gap between the demand and supply. The fuelwood consumption leading the emission of GHGs appears to be very small; however, it may have cumulative effect on climate change in near future. The potential solution of this problem could be reduction in anthropogenic effect on forests, sustainable fuelwood harvesting and mass scale afforestation for reducing pressure on forests. Renewable energy will play a major role in meeting future energy needs, in a sustainable way, in particular in rural India; this sector has, therefore, to be promoted. Wasteland constitutes a major part of country which should be developed into woody vegetations to meet the future demands of fuelwood and timber. The information obtained from the present study on fuel wood consumption pattern could form the basis for designing appropriate technologies and management policies for energy plantations in the region.

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