Assessment of fuel choices in a hilly region of Uttarakhand, India

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Abstract: In India, nearly 86% of rural households use biomass for cooking. Easy availability of fuel wood and prolonged winters increases its amount and usage in hilly regions. In the present study, to identify the current status of fuel consumption pattern of rural areas in a hilly region, three villages namely Naugaon, Mawana and Kota from the Pauri district of Uttarakhand were selected. A questionnaire was prepared comprising of queries related to socio-economic status, choice of fuels for cooking, health and social awareness among women. Estimation and comparison between greenhouse gas emissions from the burning of LPG and fuel wood were made. It was observed that monthly expenditure on LPG and fuel wood use per household was almost similar. The biomass energy is the fuel of choice in the region as sustainable fuel type. The fuel choices in rural and hilly regions of developing countries have also been discussed in brief.

Keywords: hilly region; fuel wood; indoor air quality; health impacts; socio-economic factors; forest management; India.


Biographical notes: Rajni Dhyani completed her PhD in May 2017, from the Academy of Scientific and Innovative research (AcSIR) at the Environmental Science Division, CSIR-Central Road Research Institute, New Delhi, India. She has nearly eight years of experience on various R&D and consultancy projects related to in environment impact assessment of roads, buildings, and metro rail corridor projects, air pollution studies and air pollutant dispersion modelling, fuel consumption and emissions studies. She has publications in peer reviewed journals and international conferences.
1 Introduction

A major proportion of the energy in a household in hilly areas is consumed for cooking, boiling water and space heating purposes. Cost and availability are the two major factors which drive the selection of the fuel for household use. All over the world, around 3 billion people cook and heat their homes using solid fuels, i.e., charcoal, coal and biomass comprising of fuel wood, animal dung, twigs, leaves, crop residue, etc.

While selecting a fuel for household, health impacts of biomass or other solid fuel are mostly not considered by the users. Various studies (Kurmi et al., 2012; WHO, 2014) have concluded that biomass burning is one of the major cause of indoor air pollution. Globally, 4.3 million deaths were attributable to household air pollution nearly double the fatalities as compared to the outdoor air pollution (2.3 million in the year 2012) mostly in low and middle-income countries. In fact, South-East Asian and Western Pacific regions have the highest number of fatalities, accounting for approximately 1.69 and 1.62 million deaths respectively in the year 2012 (WHO, 2014). Ndwiga et al. (2014) summarised that biomass fuel chain in rural households includes gathering, transportation, processing and combustion of fuel wood and almost all these activities are carried out by women. India is the world’s largest consumer of fuel wood (FAO, 2010). About 49% of the households in India use fuel wood, while 16.8% of household uses other biomass fuels (e.g., crop residue, dung cakes, etc.) 28.5% liquefied petroleum gas (LPG)/piped natural gas (PNG). Thereby, 65.8% of Indian households still depend on upon biomass energy for cooking, etc. According to an estimate, rural India meets 85.7% of its fuel demand for cooking from biomass burning (Census of India, 2011). Further, in nearly ten states of India (out of 29 states), fuel wood is used for cooking in nearly 60–80% of the households (Nayak et al., 2013). High demand of fuel wood not only adversely affect the landscape, reduces carbon sink but it causes serious health issues also (Nautiyal, 2011).

1.1 Fuel wood consumption and availability

The forest constitutes 22% of India’s geographic area which has increased marginally at a rate of 0.46% per annum between the years 2001–2010 (MoEF, 2011). According to an estimate (FAO, 2002), India’s consumption of fuel wood is about five times higher than what can be sustainably removed from forests. Although a large percentage of this fuel wood is grown and managed outside the forests.

Irregular supply and escalating cost of fossil fuels (e.g., LPG) discourage the use of cleaner fuels in developing country like India. People have to travel long distances to fetch wood from the forest or nearby areas. Average time taken varies between 5hr/day
on every alternate day and distance travelled between 1 to 10 km/day in search of
firewood depending upon the ecological environment. Drudgery involved in the
gathering of fuel wood from the forest and using it as end user makes the women suffer
health hazards at all stages of biomass fuel chain (ESMAP, 2004).

Cold climate throughout the year in the hilly regions raise the demand for fuel. Apart
from cooking, fuel is also required for boiling water and space heating in hilly regions.
The rural population of Indian hill states depends largely on biomass to meet their energy
demand. Solid fuels comprise more than 50% of all another fuel type they use for
cooking (Agnihotri and Maithani, 2015).

In fact, even households with LPG connections (29.4%) seldom use it (e.g., during
the arrival of some guest for making tea) for cooking purposes, due to easy availability of
fuel wood (Census of India, 2011).

In Uttarakhand, a hill state of India, ~69% of its population is rural. Forests constitute
~45% of its geographical area (GoUK, 2015). Prolonged winter results in higher annual
consumption of dry wood energy that is much higher than in other parts of India. Nearly
70% of rural households use biomass (63.3% fuel wood; 1.5% crop residues; 3.9% cow
dung cake) as primary fuel for cooking. The demand is mostly fulfilled by dry wood
(Pandey and Tyagi, 2012). Cleaner fuels like LPG are beyond the reach of inhabitants
due to socio-economic conditions and comparatively easy availability of fuel wood
(Chadchan and Shankar, 2014; Dhanai et al., 2015).

1.2 Health impacts of household fuel wood burning in India

Traditional biomass burning stoves (or Chulhas), mostly used in developing countries
particularly in rural areas, emit pollutants which result in indoor air pollution. Biomass
burning (solid fuels) releases various pollutants, which have adverse health impacts.
Traditional stoves are not energy efficient, thus emit considerable amount of health
deteriorating pollutants including particulate matter (PM), carbon monoxide (CO),
formaldehyde, trace metals and poly aromatic hydrocarbons (PAH) such as benzo(α)
pyrene, etc., (Chankapure et al., 2011; Padmanabhan, 2015). It has been estimated that
exposure to solid fuels used for cooking in developing country is the cause of 3–4% of
the global burden of diseases (Smith and Mehta, 2003; Lopez et al., 2006).

In rural India, solid fuels including biomass used for cooking and heating contribute
significantly to indoor air pollution. Biomass is burnt in inefficient stoves which are made
of mud or metal in poorly ventilated kitchens. Indoor air pollution is second biggest killer
after high blood pressure in India (CSE, 2013), around 1.3 million people died (30% of
global deaths due to indoor air pollution) of indoor air pollution in 2010 whereas death
because of outdoor air pollution was around 0.62 million (Chauhan, 2013). Women and
small children are primary victims of indoor air pollution, especially from the smoke
during cooking, as they spend considerable time indoors and mostly with their mothers.

Approximately 80% of rural households in India still use unprocessed solid biomass
like wood, dung and agricultural residue for domestic cooking and room heating (Lahiri
and Ray, 2000). In India, every year nearly 0.5 million women and children below the
age of five years die from indoor pollution resulting in acute respiratory infections (ARIs)
Smith (2000). Various studies based on impacts of biomass burning in households of
developing countries, observed a significant increase in the risk of ARIs in children and
chronic obstructive pulmonary disease (COPD) in women. Few other studies (Edelstein
et al., 2008; WLF, 2011) have reported that by-products of biomass burning as cooking
fuel could lead to lung cancer, asthma, tuberculosis, pneumonia in women and children. Poor ventilation in rural housing leads to indoor air pollution problems and aggravate adverse health impacts (Bruce et al., 2000; Fullerton et al., 2008). In another study, Revathi et al. (2012) concluded that the adverse effects of biomass fuel on lung function could be due to exposure to high concentration of pollutants liberated by biomass fuel combustion and inadequate ventilation.

2 The study areas

Pauri Garhwal (referred as Pauri subsequently), a district of Uttarakhand state (India) encompasses an area of 5,230 sq. km and situated between 29° 45’ to 30° 15’ latitude and 78° 24’ to 79° 23’E longitude. The district is a part of the Western Himalayas. The study was carried out in the three villages of the Pauri district, namely Naugaon, Mawana and Kota (Figure 1). The villages selected had almost similar weather conditions.

Figure 1 Study locations (see online version for colours)

2.1 Climatic conditions

The region has a sub-temperate to temperate climate. Temperature descends to a minimum of 1.3°C in January and means monthly temperature for the region ranges from 25°C to 35°C (Figure 2). Average annual rainfall in the district is 218 cm, nearly 90% of which is generally concentrated over the monsoon. Relative humidity varies between 54% and 63% (GoUk, 2015). Higher reaches receive some snow in winter when the temperature falls to freezing point. The topography of Pauri is rugged and almost entire region is mountainous. Terrace farming is practiced in the large part of the district (GoUk, 2015).
Figure 2  Monthly variations in average temperature in Pauri district (see online version for colours)

Table 1  Brief description of villages selected for the present study

<table>
<thead>
<tr>
<th>Description</th>
<th>Naugaon</th>
<th>Mawana</th>
<th>Kota</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of the village(s) (district Pauri, Uttarakhand, India)</td>
<td>29°57'42.99&quot;N 78°51'53.63&quot;E</td>
<td>29°57'56.30&quot;N 78°51'59.26&quot;E</td>
<td>30°01'00.61&quot;N 78°51'49.43&quot;E</td>
</tr>
<tr>
<td>Latitude longitude</td>
<td>1,500</td>
<td>1,524</td>
<td>1,229</td>
</tr>
<tr>
<td>Height above mean sea level (MSL) (m)</td>
<td>219.42</td>
<td>-</td>
<td>198.30</td>
</tr>
<tr>
<td>Area (ha.)</td>
<td>26</td>
<td>22</td>
<td>40</td>
</tr>
<tr>
<td>Total no. of houses</td>
<td>103</td>
<td>100</td>
<td>156</td>
</tr>
<tr>
<td>Population (nos.)</td>
<td>52</td>
<td>NA*</td>
<td>67</td>
</tr>
<tr>
<td>Male (nos.)</td>
<td>51</td>
<td>NA*</td>
<td>89</td>
</tr>
<tr>
<td>Female (nos.)</td>
<td>58</td>
<td>NA*</td>
<td>62</td>
</tr>
</tbody>
</table>

Notes: *NA-not available.

Source: Census of India (2011) and GoUk (2013)

2.2 Socio-economic characteristics

There are extensive forests (61.76%) in the district Pauri Garhwal. These forests are serving as a base for many industries, local needs of fuel wood, fodder resources and ecological stability (GoUk, 2013). The community depends primarily upon agriculture
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(crop cultivation) and forests (collection of fuel wood, fodder, fruits, seeds) for their livelihoods.

The district has a population density of 129 inhabitants/km². The population growth rate of –1.5% was observed over the decade (2001–2011). The negative growth rate of the district reflects the migration of the population due to the absence of livelihood and limited employment opportunities (Bahuguna and Belwal, 2013).

The details regarding the geographic locations, altitudes, population characteristics, etc., have been given in Table 1.

3 Methodology

Three villages namely, Naugaon, Mawana and Kota of district Pauri were selected randomly in the present study. A total of 42 household’s women were interviewed in all the three villages. In each of these three villages nearly 14 households (~50% of households) were interviewed as rest of the 50% houses could not be covered because of their refusal/ hesitation to participate in the study due to some or the other reasons.

A questionnaire was developed to carry out household survey to assess the awareness among women on the biomass fuel burning and related health impacts. The questionnaire was prepared by keeping women as primary respondents, as they are responsible for fetching fuel wood from local forest, cooking and they spend maximum time in the kitchen. The questionnaire comprised the queries related to fuel choice, daily/monthly consumption pattern of fuel, source of fuel, frequency, average distance of travel to fetch fuel wood, kitchen and details of ventilation source (e.g., dimensions, etc.) as well as time spent by them in the kitchen. Women were enquired about any health issues or problems while cooking on traditional fuel wood stoves. They were further asked about their awareness on adverse health impacts of traditional stoves (smoke) and if they want to switch to some other cleaner fuel if they are given such choice. Questions about socio-economical characteristics of household (e.g., type of house, monthly income of family, electricity connection, water connection, etc.) which directly or indirectly influence the choice of fuel to be used were also included in the questionnaire.

4 Results and discussions

4.1 Socio-economic conditions

The questionnaire developed for the study was divided into three sections, comprising individual’s details, socio-economic factors and awareness amongst women on adverse health impacts from the usage of traditional stoves.

Naugaon and Mawana villages are more or less on similar altitude (~1,500 m) with temperate climatic conditions, while Kota village is at relatively lower elevation (~1,200 m) and had slightly higher temperatures of 1–2°C (Table 1). All the three villages have temperate climatic conditions with prolong winters, 95% of the houses interviewed in these villages, own farmlands and cattle. Female members of the households had responsibility of farming, to fetch fuel wood and cooking meals for the family, etc.
Out of three villages, Naugaon and Mawana not connected with roads and only way to reach to these two villages was by walking/trekking (nearly 2 km from main road), whereas, Kota had motorised road till periphery of the village.

Socio-economic comparison between the three villages has been given in Table 2. Naugaon had higher literacy rate among women as compared to Kota and Mawana. All the three villages had a mix of kaccha (houses made of mud and stone) and pacca houses (houses made of brick, cement and iron) reflecting economical status of the residents of villages. Almost every household in all the three villages had electricity connections. Potable water was accessible to all in these three villages, mostly by community water taps (provided by the gram panchayat or local self-government) and in few cases by individual water taps inside the house. All the households interviewed in the Naugaon village had toilet facility, followed by ~85% in Kota and ~33% in Mawana village.

Table 2 Summary of Socio-economic indicators of three villages

<table>
<thead>
<tr>
<th>Socio-economic factors</th>
<th>Naugaon</th>
<th>Mawana</th>
<th>Kota</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of households surveyed</td>
<td>n = 13</td>
<td>n = 15</td>
<td>n = 14</td>
</tr>
<tr>
<td>Age (yr) (Avg ± SD)</td>
<td>34 (±12.45)</td>
<td>40 (±10)</td>
<td>56 (±17.35)</td>
</tr>
<tr>
<td>Education (n = 13)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Illiterate</td>
<td>2</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>• Up to 5th standard</td>
<td>1</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>• High school</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>• Inter school</td>
<td>7</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>• Graduate and above</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>• Type of house(s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaccha (mud and stone) (%)</td>
<td>39</td>
<td>87</td>
<td>29</td>
</tr>
<tr>
<td>Pacca (cement and iron) (%)</td>
<td>62</td>
<td>13</td>
<td>71</td>
</tr>
<tr>
<td>Members in family (Avg ± SD)</td>
<td>5 (±1.6)</td>
<td>6 (±2)</td>
<td>4.6 (±1.9)</td>
</tr>
<tr>
<td>Children in family (Avg ± SD)</td>
<td>1.53 (±1.13)</td>
<td>2.14 (±1.8)</td>
<td>2.2 (±0.8)</td>
</tr>
<tr>
<td>Family monthly income (Avg, ±SD, range)</td>
<td>*US$ 162 (±US$ 203/–)</td>
<td>US$ 67 (±US$75/–)</td>
<td>US$ 208 (±US$202/–)</td>
</tr>
<tr>
<td>(US$ 16–621/–)</td>
<td>(US$ 16–234/–)</td>
<td>(US$ 13–621/–)</td>
<td></td>
</tr>
<tr>
<td>Electricity (%)</td>
<td>100</td>
<td>93</td>
<td>100</td>
</tr>
<tr>
<td>Access to potable water (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Water connection inside house (%)</td>
<td>69</td>
<td>-</td>
<td>29</td>
</tr>
<tr>
<td>Community water tap (%)</td>
<td>31</td>
<td>100</td>
<td>71</td>
</tr>
<tr>
<td>Toilet facility in the house (yes)</td>
<td>100</td>
<td>33</td>
<td>86</td>
</tr>
</tbody>
</table>

Note: *1US$ = 64.42 Indian Rupee.

The average monthly income of households in Nauagao and Kota were almost similar (US$ 155/– to 210/–) (1US$ = ~64.42 Indian Rupees). However, village Mawana households’ had low average monthly income (~US$ 62/–). In Mawana village, male members of the family were the earning members and most of them worked as daily wage labourers earning nearly US$ 16/– month. Average monthly income of people of Naugaon and Kota village was almost double from people of Mawana.
However, despite the higher average income of people of Naugaon and Kota villages, nearly 50% of the households interviewed had income of less than US$78/- per month in the two villages (Table 2).

In the present case, in most of the houses surveyed in all the three villages had one room dedicated as a kitchen. However, joint families residing in an old constructed house (in Mawana village) were forced to cook and reside in the same place (room) due to space constraint. In the households surveyed, few kitchens were made in shanties (temporary structure) adjoining the house due to space constraint and in a few households mud stoves were made outside their houses in open depending on the weather, they were mostly used in morning hours only. About 80% of the houses in Naugaon and Kota village had dedicated kitchens in their houses as compared to only 45% in Mawana village.

It was observed that, women spend nearly 3–4 hours of a day in kitchen to prepare three meals on an average. The average areas for the kitchens were measured to be around 5 m$^2$ and nearly 63% of all surveyed houses were provided with a window as a source of ventilation in the kitchens with highest 73% households in Kota village followed by ~60% at village Naugaon and ~55% in village Kota.

Nearly 70% of the household in Naugaon and Kota village had both LPG connections as well as traditional biomass (fuel wood) burning stoves as a source/fuel for cooking. Further, in Mawana village more than 90% of the household were totally dependent on traditional biomass burning stoves for cooking and only 7% of the total households had LPG connection.

### 4.2 The fuel choices

In Naugaon and Kota village, when asked further about preferred choice of fuel for cooking, it was startling observation that nearly 80% of the household still uses and prefer fuel wood as primary fuel for cooking and LPG cylinders were used only on special occasions like on arrival of some guests. This finding was further confirmed that households of these villages on an average consume one LPG cylinder (14.2 kg of LPG/cylinder) for three months and in one case, a LPG cylinder was used for a year.

The main reason for fuel wood as fuel of choice was easy availability and economic condition of the households. Use of cow dung as a fuel was found to be negligible in these villages.

During the survey, it was found that women were responsible for collection of wood from local forest. Questions were also asked about the availability of fuel wood, frequency and distance of their travel for wood and average fuel + wood they bring in one trip (kg). In Naugaon and Kota households were paying US$25–32 in every 3–4 months (~US$ 78 per annum) to wood cutter for cutting tree branches and dead wood collection into desired sized logs and their transport to the houses which are stocked for 3–4 months after which process is repeated (Table 3).

According to the villagers of Naugaon and Kota, they were spending money on fuel-wood instead of opting for other cleaner fuel such as LPG because they could not afford the high price of the LPG cylinder. Moreover, the irregular/limited supply of LPG cylinders (reported to be about once in 3–4 months) also restricts the usage of LPG cylinders in the villages.
Table 3  Fuel-wood consumption pattern at selected villages

<table>
<thead>
<tr>
<th>Fuel-wood used</th>
<th>Naugaon</th>
<th>Mawana</th>
<th>Kota</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chir, Banj, Toon, Bhandir Payan, Padam*</td>
<td>Chir, Banj, Toon, Bhandir Payan, Padam*</td>
<td>Banj, Toon, Bhandir, Payan, Padam*</td>
</tr>
<tr>
<td>Average usage of fuel wood (kg/day/household)</td>
<td>11 (~4 tonne/yr/household)</td>
<td>10 (~3.5 tonnes/yr/household)</td>
<td>10 (~3.5 tonnes/yr/household)</td>
</tr>
<tr>
<td>Availability of fuel wood</td>
<td>Local forest</td>
<td>Local forest</td>
<td>Local forest</td>
</tr>
<tr>
<td>Distance travelled to collect fuel wood (km)</td>
<td>• Quarterly Rs. 1,500/– to 2000/– paid by per household as contract for cutting tree branches and their transport to their houses.</td>
<td>3–4 km</td>
<td>• Quarterly Rs. 1,500/– to 2000/– paid by per household as contract for cutting tree branches and their transport to their houses.</td>
</tr>
<tr>
<td>Travel frequency</td>
<td>once in 3 days</td>
<td>~20 kg in a trip</td>
<td>• Wood stocked last for 3–4 months, thereafter process is repeated again.</td>
</tr>
<tr>
<td>Gross weight of fuel woods they carry (kg)</td>
<td>• Wood stocked last for 3–4 months, thereafter process is repeated again.</td>
<td>• In few cases, those who cannot afford to pay rupees lump sum, have to travel around ~2–3 km daily for collection of fuel wood.</td>
<td>• In few cases, those who cannot afford to pay rupees lump sum, have to travel around ~2–3 km daily for collection of fuel wood.</td>
</tr>
</tbody>
</table>

Note: *Pinus roxburghii (Chir), Quercus leucotrichophora (Banj), Rhus punjabencis, cedrela (Toon), Albizzia lebbek (Bhandir), Prunus cerasoides (Payan, Padam)

At Mawana village, due to fear of wild animals in the forest, women travel in groups ~3–4 km every 2–3 days for fuel wood and each of them carry back ~20 kg (on an average) of fuel wood (Table 3). As told by the women of Mawana village, higher price was the primary constraint which inhibits them to use fuel like LPG or even kerosene, as an alternate to fuel wood.

The villagers at Naugaon and Kota spend nearly ~US$ 78 annually on fuel wood, which is nearly equal to 12 subsidised LPG cylinders [@Rs. 420/– (~US$ 7) per cylinder]. Apart from cooking, the fuel wood is used for space heating, boiling water, etc., as all these requirements could not be fulfilled by energy provided by a LPG cylinder in a month (Table 4).

Unlike the metro cities in India, where mostly door-to-door supply of LPG cylinders/PNG is provided, in hills, consumer themselves have to carry cylinders to the LPG re-filling point. Due to hilly terrain, door-to-door LPG service is quite difficult and one need to pay additional Rs. 150–200/– per cylinder for its transportation to the respective village situated at the upper reaches of the hills.
Table 4 Consumption and cost comparison of LPG and fuel wood among the villages

<table>
<thead>
<tr>
<th>Average members in a family (nos.)</th>
<th>Average LPG consumption (per household)</th>
<th>Average fuel wood consumption (per household)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of cylinders/year/family*</td>
<td>Annual cost (US$)</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-----------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Naugaon = 5</td>
<td>11</td>
<td>73</td>
</tr>
<tr>
<td>Mawana = 6</td>
<td>13</td>
<td>98</td>
</tr>
<tr>
<td>Kota = 4.6</td>
<td>10</td>
<td>67</td>
</tr>
</tbody>
</table>

Notes: *@2.6 kg LPG/capita/month; 1Standard weight of a LPG cylinder is 14.2 kg; 2@Rs. 420/LPG cylinder; Fuel wood is available for free.

Irregular and uncertainty in the supply of LPG discourages the people to switch from fuel wood to LPG as primary fuel for cooking. In the village Mawana, drudgery is involved in fetching fuel wood from the forest, but fuel wood is free of cost, which saves nearly US$ 78/- annually, which is a significant amount in view of their annual income (Table 4).

During the interview, many villagers preferred to cook on fuel wood stoves. They consider it as their tradition/custom and according to them food cooked in fuel wood is more healthy and tastier as compared to food cooked using LPG/kerosene. This notion also adds to their reluctance to switch to cleaner fuels.

The fuel wood cycle comprises of collection, combustion, compensatory plantation and its maintenance. According to the villagers, fuel wood consumption for domestic use/purpose is sustainable due to low population and effective compensatory plantation by them. Compensatory plantation (four plants in place of every single tree cut) is carried out preferably at the same site from where the tree has been cut. The maintenance is in the hands of the villagers if plantation has been carried out in the village, otherwise if plantation has been done in the forest, their maintenance is carried out by district ‘Van Panchayat (VP)’ (also called as Forest Protection Committee and is a locally elected body) or district forest department (Negi et al., 2012). Even though compensatory afforestation is carried out in the villages, it effective management is important for continuous supply of fuel wood.

4.3 Health issues among women

In the questionnaire, a separate section was devoted to awareness among women on health related issues from burning fuel wood in traditional stoves and also any other health issues besides their willingness to switch to some other cleaner fuel(s), etc. When asked about adverse health effects of biomass burning in traditional stoves, nearly 50% of the women in all three villages was aware of it. In the questionnaire, a separate section was devoted to awareness among women on health related issues from burning fuel wood in traditional stoves and also any other health issues besides their willingness to switch to some other cleaner fuel(s), etc.

The Naugaon village has better socio-economic condition as compared to Mawana and Kota. Naugaon has higher literacy rate and it is better in socio-economic status in
terms of house type, availability of water, electricity, average monthly family income. Nearly \( \sim 60\% \) of the households in the village Naugaon have a dedicated kitchen and \( \sim 70\% \) have LPG connections. However, even after better literacy rate and socio-economic conditions only \( \sim 54\% \) women were aware about the adverse health impacts of traditional chulhas. Nearly, 62\% of women reported the health issues like cough, eye burning while cooking in traditional chulhas in addition to that chronic pain in legs and arms was also reported which could be due to \( \sim 3 \) km travel to fetch fuel wood (Table 5).

Table 5  
Health related issues among women in selected villages

<table>
<thead>
<tr>
<th></th>
<th>Naugaon</th>
<th>Mawana</th>
<th>Kota</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size (no. of women interviewed)</td>
<td>n = 13</td>
<td>n = 15</td>
<td>n = 14</td>
</tr>
<tr>
<td>Awareness about adverse health impacts of biomass burning (%)</td>
<td>Yes 54</td>
<td>80</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>No 46</td>
<td>20</td>
<td>29</td>
</tr>
<tr>
<td>No health problem (%)</td>
<td>38</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cough, eye burning while cooking (%)</td>
<td>62</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Any other health issues reported</td>
<td>• Cataract-one person</td>
<td>• Eye damage due to smoke-one person</td>
<td>10 out of 14 samples reported health issues like chest problem, headache, severe eye pain, headache, weak eyesight, knee pain, stomach ache, eye burning, breathing problem cataract, etc.</td>
</tr>
<tr>
<td></td>
<td>• Severe cough, dizziness-one person</td>
<td>• Chronic cough and headache-one person</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Chronic pain in back, arms and legs-one person (interviewed woman travels 3 km to fetch fuel wood)</td>
<td>• Tuberculosis-one person</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Weak eyes and stomach ache-one person</td>
<td>• Breathing problem, headache and stomach ache-one person</td>
<td></td>
</tr>
</tbody>
</table>

Mawana village has poor socio-economic conditions as compared to the other two selected villages. Only 13\% of the village has pacca house and the monthly average income was less than half (\( \sim \) Rs. 4000/-) of the Naugaon and Mawana and only 33\% of the houses in the village had toilet facility. Due to poor economic conditions only 45\% houses had dedicated kitchen and \( \sim 7\% \) of the households have LPG connection. However, the village had highest awareness (100\%) about the adverse health impacts of fuel wood use for cooking. All women survey in the village reported various kinds of
diseases such as cough, eye irritation, and breathing problem and linked it with regular use of fuel wood for cooking (Table 5).

As indicated in Table 2, the Kota village has lowest literacy rate. However, the economic condition was better than the other two villages surveyed. ~80% of the houses had dedicated kitchen and like Naugaon ~70% household has LPG connection. Nearly 70% women surveyed were well aware of the adverse health impact of fuel wood burning and all reported cough, eye burning while cooking and other related health impacts.

In fact, irrespective of the socio-economic conditions and drudgery involved, in all the three villages ~80% of the households prefer fuel wood for cooking and use the LPG stoves occasionally which is mainly due to non-availability of LPG and cost involved.

It is quite possible that fuel wood burning during cooking could be one of the major reasons of these health impacts. More than 50% of the women were willing to bring few changes into their kitchen (window and chimney) to improve ventilation. Main reasons for denial of other (50%) women were related to their financial constraints or due to no scope to bring in changes in existing structure of their house.

The emissions released per household from traditional wood burning stoves were estimated and compared with emissions from LPG (Table 6). Biomass is considered carbon neutral (IPCC, 2015), therefore, CO₂ emission was not estimated for the fuel wood. Emissions from fuel wood were estimated to be ~200% higher than LPG. In all three villages if we compare emissions CO emissions were highest emissions followed by NMVOC, methane, NOₓ and N₂O.

<table>
<thead>
<tr>
<th>Emissions (gm/month/household)</th>
<th>Naugaon LPG#</th>
<th>Fuel wood</th>
<th>Mawana LPG#</th>
<th>Fuel wood</th>
<th>Kota LPG#</th>
<th>Fuel wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>2.60</td>
<td>1,495</td>
<td>3.12</td>
<td>1,359</td>
<td>2.4</td>
<td>1,359</td>
</tr>
<tr>
<td>N₂O</td>
<td>0.07</td>
<td>20</td>
<td>0.0780</td>
<td>18</td>
<td>0.060</td>
<td>18</td>
</tr>
<tr>
<td>NOₓ</td>
<td>NA##</td>
<td>455</td>
<td>NA##</td>
<td>414</td>
<td>NA##</td>
<td>414</td>
</tr>
<tr>
<td>CO</td>
<td>26</td>
<td>22,770</td>
<td>31.2</td>
<td>20,700</td>
<td>23.9</td>
<td>20,700</td>
</tr>
<tr>
<td>NMVOC</td>
<td>2.60</td>
<td>2,732</td>
<td>3.12</td>
<td>2,484</td>
<td>2.392</td>
<td>2,484</td>
</tr>
</tbody>
</table>

Notes: *Based on IPCC emission factor (IPCC, 1997; FAO, 1999; IPCC, 2006); #Emission factor for LPG-Smith et al. (2000); ##Not available.

If the fuel wood consumption use for household purposes is evaluated, it appears that selection of fuel wood is not a wise choice from health and emissions point of view. However, it has been observed and reported in various studies that if proper ventilation is provided by considering designs for better exchange of air from outside or improved cook stoves (ICS), considerable reduction in the emissions could be achieved even after the use of fuel wood as fuel (Baris et al., 2006; PA, 2015). It was reported that various interventions in kitchens like smoke hoods, windows, efficient combustion through improved stoves could reduce particulate and CO pollution in homes by nearly 80% (PA, 2015).

According to Smith (2006) properly dried fuel wood, improved stoves with well ventilated kitchens can reduce indoor air pollution substantially.
4.4 Policy interventions in India

In India, efforts have been made in the past by concerned agencies for reduction of smoke and resulting indoor air pollution emitted from traditional stoves. One such important step towards reduction of indoor air pollution was providing ICS (Kishore and Ramana, 2002), National Programme on Improved Chulha (NPIC) was initiated by government of India in year 1985 (Sinha, 2002). During this programme over 30 million ICS/stoves were installed between 1985 and 2002. However, the programme was considered unsuccessful, as most of the users who adopted ICS later on switched back to their traditional stoves, because of various issues related to their low durability, complicated usage, unsatisfactory performance, specific fuel requirement (quality of wood, chopped in small pieces) (Sinha, 2002; Edelstein et al., 2008; Bhojvaid et al., 2014).

In the recent past, under the 11th Five Year Plan (2012–2017), project titled ‘Unnat Chulha Abhiyan’ (or mission improved cook stove) has been initiated by Ministry of New and Renewable Energy (MNRE), Government of India. Under this programme 2.5 million ICS will be distributed. However, such initiatives becomes successful only by creating awareness and educating the target population on the issue, participation of government and general public, rather than disseminating improved stoves without involving them in the initiatives (Edelstein et al., 2008; Bhojvaid et al., 2014). A recent welfare policy initiative ‘Pradhan Mantri Ujjwala Yojana (PMUY)’ is launched by Government of India on 1 May 2016. Its aim is to safeguard the health of women and children by providing them with a clean cooking fuel – LPG. Under this scheme, 0.5 billion LPG connections will be provided to below poverty line (BPL) families with a support of ~US $24.8 (Rs. 1,600–) per connection in the next three years. The connections are issued in the name of women of the households. Preference is given to schedule caste/schedule tribe (SC/ST)/BPL families and the states having lower LPG coverage than the national average as of 1st January 2016. The number of beneficiaries of Pradhan Mantri Ujjwala Yojana for providing free of cost LPG (cooking gas) connections to BPL households has crossed 20 million (2 crore) mark since its launch in May 2016 (IOA, 2017). In Uttarakhand the scheme was launched in 9 June 2016 with aim at replacing use of firewood with LPG. Under this scheme, it is plan to improve the LPG distribution system to increase the number of distributorship from 239 to 400 by creating a new category of distribution of LPG in hilly regions called ‘Durgam’ (meaning unreachable in English). Further, it is also planned to increase the capacity of the existing bottling plants in Uttarakhand (PMUY, 2017).

4.5 Sustainable fuel wood management

In the present case, in all the three villages 50% of the population had monthly income ≤ Rs. 1,000– (~US$15). Thus, it could not be expected from the households to spend ~40% of its monthly income on cleaner fuel like LPG [@~Rs. 420–(or ~US$ 7) per cylinder] which will last for a month if used for various domestic purposes. Most of the women interviewed, want to switch to LPG from fuel wood only if LPG is provided for free or at highly subsidised rate. However, LPG (although subsidised for domestic consumer by government) is a non-renewable source of energy and its price is governed by international market. Therefore, it is unlikely that LPG prices are going to come down in near future and its availability is not reliable due to accessibility and transportation in hilly terrain. Personal exposure and emissions from fuel could be reduced by ICS or
brining a few changes to improve ventilation in the kitchen. Drudgery involved in bringing the fuel wood and paying (nearly Rs. 5,000/– per year) for fuel wood could be reduced by practicing sustainable fuel wood management.

Therefore, for regular and cheap source of energy in the rural areas of hills, economically and environmentally sustainable options should be explored. Low population density and availability of land in the villages of hilly regions favours the authority and community participation in forest management practices.

Developing countries, where population dependency on fuel wood is high, have started various initiatives to optimise the use of fuel wood and other methods to create balance between fuel wood supply and ecological well being. Bhutan has its 70% population dependency on fuel wood, the country has initiated a project with UNDP called sustainable rural biomass energy (SRBE) project to promote the use of biomass energy resources for cooking, heating and lighting in rural areas thorough gradual utilisation of biomass-based energy systems and efficiency improvements (ICGG, 2014). Similarly, in the Philippines, wood is used as primary source of energy and to ensure the regular supply of fuel wood and simultaneously preventing degradation of forest, marginal and wasteland were planted with fast growing tree species and managed by private landowners (FAO, 2010). However, it is important to prevent over exploitation of forests. Therefore, management strategies, which included participation and cooperation of all stakeholders, especially the rural dwellers, should be encouraged with aim at balancing wood use as fuel and other traditional uses (Githiomi and Oduor, 2012; Heikkinen, 2011).

Forest conservation is a major component of sustainable development efforts (Krishnaswamy, 1995). In India, concepts like social forestry (started in year 1976), joint forest management (started in year 1988) have been practiced for decades for sustainable development. Social forestry aims to achieve rehabilitation of degraded land, strip plantation, developing woodlots on common properties and collection, processing and management of forest products by involving local communities. Similarly, in joint management of existing forests, planting of fuel wood trees on non-forest areas and promotion of other fuels/energy sources appear to be sustainable alternative options for protecting the forests and meeting the household and commercial energy needs (Lun et al., 2014; Hegde et al., 1999).

In Uttarakhand, community forest management is known as VP has been active since decades. It is unique system in which government and villagers’ participates to protect and manage forests. The rules and regulations devised by each VP village committee are unique from one VP to another. These VPs are responsible for internal management of local forests and grazing, collection of fuel wood, fodder, timber and protection. However, recent changes in policy have led to institutional complexities and uncertain incentives have reduced participation of local public in management of the forests (Hussain et al., 2013; Matta et al., 2005). Now, they are merely informed about the actions by the concerned agencies, which have reduced their interest in such initiatives.

Various studies (Sati and Song, 2012; Mohan et al., 2009) carried out in the Uttarakhand hilly regions have suggested cooperation of locals in sustainable forest management, agro-forestry, joint forest management for fuel wood and better ecological health. Such approach not only provides regular supply of fuel wood to the villagers but also restores the fragile ecosystem. Khuman et al. (2014, 2015) studied fuel wood consumption pattern in the villages of hill regions of Uttarakhand and Manipur. Their
studies revealed that fuel wood consumption pattern varies from region to region depending upon their availability, access to resources, local food and cooking practices. Therefore, policy decisions should be made only after comprehensive study of factors influencing the supply, consumption pattern and local issues.

5 Conclusions

The present study was conducted in three villages namely Naugao, Mawana and Kota situated in district Pauri (Uttarakhand, India). Socially and culturally, the villages studied were similar. Even with high percentage of LPG connections in two villages, the households were using fuel wood as primary fuel for cooking. The reason for such preference was attributed to high cost of LPG cylinders and poor supply/availability. The fuel wood consumption was not an ecological issue for the villagers. However, in the long run, frequent forest fires and demand of fuel wood could degrade the region forests.

Primarily, financial issues and sometimes-social issues/customs discourage villagers to switch over to cleaner fuels and bring modifications in the kitchen. Nearly all (100%) of the women interviewed, were willing to switch over to cleaner fuel or technologies, if provided at subsidised rate or for free. However, due to high cost and irregular supply of LPG, recommending LPG as a substitution of fuel wood does not seems a rational option.

As the villages have low population, fuel wood could be made a long-term sustainable and workable option as fuel if social forestry and community forestry is adopted more effectively. In addition, approaches such as afforestation could address energy supply issue and offer employment opportunities to the villagers. Apart from that, out flux of population could also be reduced if sustainable approaches like afforestation could be adopted which will supply energy to the community but also employment opportunities to the villagers. Due to existing system of VPs or district forest departments, this could be achieved. Attempts should be made to establish a local framework for generating a sustainable forest economy (Sati and Song, 2012). These types of forest management practices could be explored for regular and sustainable supply of fuel wood and other forest produce without exploiting and degrading the natural forests of the region. Fuel wood is considered carbon neutral as they fix the carbon in their lifetime, therefore, fuel wood could be used as fuel if produced sustainably.

However, to reduce the health impacts of fuel wood burning during cooking, it is suggested to provide hopper/hood over the traditional stoves, etc. Sustainable way of social forestry, induction of improved technologies in cook stoves and changes in kitchen designs for better ventilation could help in fuel supply and reduce adverse health impacts.

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