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ORIGINAL RESEARCH

Utilization pattern of biomass energy and socioeconomic dimensions associated with Yelandur, Karnataka, India

H. P. Komala · Attimogge Girirajanna Devi Prasad

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Abstract Energy is considered as a key factor which determines the economic development in the entire sector of any region. Biomass is one of the primary energy sources in rural areas. The study was carried out to examine the utilization pattern of biomass energy and socioeconomic dimensions associated with rural areas of Yelandur, Karnataka, India. Field studies in these villages covering 645 households were made to collect the data and assess the socioeconomic conditions that govern the biomass utilization pattern for meeting energy requirements. Firewood is the primary energy source (94.78 %) for cooking and heating among these rural folk. Most of them are illiterates (60 %) with 28.96 % of them having a meagre income. Traditional biomass stoves are used predominantly. The study shows that there is a positive correlation ($R^2 = 0.98$) between the households size and volume of firewood consumption. The study has revealed that the firewood fuels are the dominant source of energy for cooking and heating purposes.

Keywords Biomass · Firewood · Resources · Households · Socioeconomic · Utilization pattern

Introduction

One essential component of rapid economic and social development is energy. It plays an important role in the socioeconomic development of any country. To achieve development goals through energy, it requires better knowledge of how people make decisions about their energy use [1]. Biomass is one of the primary sources of energy for about 2.4 billion people in developing countries [2].

Biomass resources include wood and wood wastes, agricultural crops and their residues, municipal solid waste, animal waste, waste from food processing, aquatic plants and algae [3]. It is mainly used as fuel sources for cooking and heating purposes in the rural households. The biomass fuels in its various forms have been recognized as a useful and cost-effective alternative source of energy. It has advantages over fossil fuels due to various environmental concerns. These fuels do not contribute to the carbon dioxide levels of atmosphere and thus prevent aggravation in global warming [4].

Biomass fuel is found to be a suitable energy source that can be converted to higher energy content fuels through direct combustion, thermochemical conversion, or biochemical conversion processes [5]. Briquette (combination of two or more biomass fuels in a compressed form) is used as an alternative fuel to coal, which is easy to transport and has better handling, storage and very efficient energy sources [6]. Calorific value determines the energy efficiency of the firewood. There are numerous indicators of fuel efficiency. These may include the indoor air pollution, greenhouse effects (e.g. deforestation, CO_2 emission during production, conversion and consumption), etc. [7].

More than 70 % of Indian population lives in rural areas and they satisfy 80 % of their energy needs only from the fuelwood collected from forests and nearby sites [8]. Cooking fuels in the rural areas of India are predominantly unprocessed biofuels, such as fuelwood, crop residues and animal dung [9–12]. In Karnataka, India, considering all types of energy sources and sector-wise consumption reveals that, traditional fuels such as firewood (43.60 %),

H. P. Komala · A. G. D. Prasad (✉)
Department of Studies in Environmental Science, University of Mysore, Manasagangotri, Mysore 570006, Karnataka, India
e-mail: agdprasad@yahoo.com

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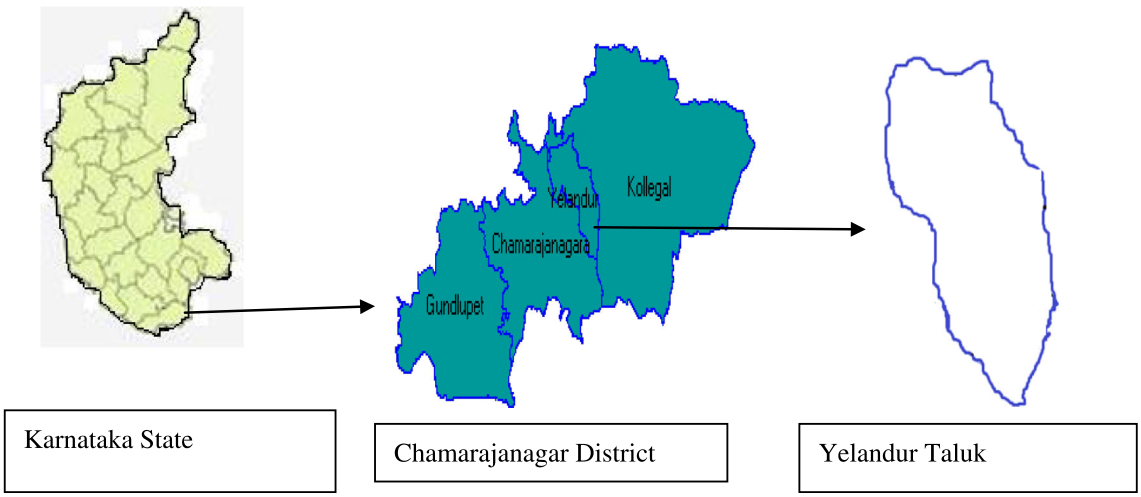

Fig. 1 Study area

agro-wastes (8.20 %) and cow dung (1.40 %) account for 53.20 % of total energy consumption [13].

The usage of biomass energy is greatly influenced by socioeconomic factors such as household size, income level, poor household access to clean energy sources and low household standard. There is a strong correlation between a household family size and the volume of firewood consumed per day [14].

The present paper highlights the utilization and consumption pattern of biomass energy resources and the socioeconomic factors associated with the villages of Yelandur taluk.

Study area: The study was carried out in Yelandur taluk of Chamarajanagar district, Karnataka, India (Fig. 1). It is located between 11°42′–12°5′ North latitude and 76°57′–77°09′ East longitudes with an area of 266.34 km^2 comprising a population of about 82170. The investigation was undertaken in four villages: A.Devarahalli, Malarapalya, Uppinamole and Katanvadi.

Methods

Based on the stratified simple random sampling technique [15], four villages were selected for collecting primary data on several household parameters through door-to-door interview. Six hundred and forty-five households were surveyed to gather the information.

The survey was conducted to identify and quantify the biomass fuel resource, consumption patterns and to record their daily demand. A questionnaire was designed to get the data on the comprehensive picture of socioeconomic conditions, energy use pattern, housing characteristics and cooking behaviours. Energy usage included information on consumption of biomass fuels and commercial fuels for cooking and heating, sources of procurement of cooking fuel, time and effort involved in procurement, and energy demand. The statistical package for social sciences (Statistical Analysis in Social Science, SPSS version 16.0 Chicago SPSS Inc.) was used for the analysis of data. The data obtained from the survey were pooled and analysed by employing analysis of variance (ANOVA), followed by Tukey’s honest significant difference (HSD) mean range test for knowing the significance at $P > 0.05$ level (probability at greater than 0.05 level or 5 %).

Results and discussion

The survey data indicated that the majority of the respondents were farmers by primary occupation and half of the fuelwood demand is satisfied through their own farmland sources. Socioeconomic characteristics of the surveyed households are given in Table 1. Among the respondents (645), the numbers of females are 59 % and males 41 %; while illiterates are 60 % and literates are only 40 %. This indicates that the literacy level is low in these villages.

The households are categorized into four classes based on the landholdings such as landless or low (below 1 acre), middle (1–5 acre) and high (above 10 acre). Among these, the landless account for 27.37 %, the households with 1–5 acre account for 39.43 %, below 1 acre account for 34.94 % and above 10 acre account for only 1.79 % of households. On an average of four villages, only 4 % of the population of households have annual income above Rs. 50,000, while 31 % around Rs. 10,000, 40 % less than Rs. 10,000 and the remaining has no fixed income. Interestingly, our survey reveals that 12.84 % of households of A.Devarahalli, 16.68 % of Malarapalya, 45.74 % of Uppinamole and 40.58 % of households of Katanvadi have no

Table 1 Socioeconomic characteristics of the household

Name of the villages	Total number of households	Respondent (n)		Respondent (%)		Land holdings (%)				Income (%)			
		Male	Female	Literate	Illiterate	Low (<1 acre)	Medium (1–5 acre)	High (>10 acre)	Nil	Low (1,000–10,000 Rs/year)	Medium (10,000–50,000 Rs/year)	High (>50,000 Rs/year)	Nil
A.Devarahalli	48	21.00 ± 1.00^{a}	29.00 ± 1.00^{a}	36.83 ± 1.61^{a}	61.83 ± 1.61^{a}	38.67 ± 1.15^{a}	44.20 ± 0.69^{a}	1.00 ± 1.73^{a}	19.20 ± 0.69^{a}	37.17 ± 1.04^{a}	47.30 ± 0.61^{a}	4.67 ± 1.53^{a}	12.84 ± 0.35^{a}
Malarapalya	182	103.67 ± 1.53^{b}	77.66 ± 2.52^{b}	52.00 ± 2.00^{b}	49.00 ± 1.00^{b}	36.00 ± 1.73^{b,c}	50.00 ± 1.73^{b}	2.01 ± 1.72^{a}	14.20 ± 1.91^{b}	56.37 ± 1.47^{b}	28.87 ± 1.03^{b}	2.67 ± 1.52^{a}	16.68 ± 0.54^{b}
Uppinamole	200	48.33 ± 1.53^{c}	151.67 ± 1.53^{c}	31.20 ± 0.72^{b}	69.13 ± 1.03^{b}	39.67 ± 1.15^{b}	21.80 ± 1.04^{b}	1.67 ± 2.89^{a}	42.07 ± 2.54^{c}	28.37 ± 1.10^{b}	27.53 ± 0.50^{b}	3.00 ± 2.65^{a}	45.74 ± 0.41^{c}
Katanvadi	215	95.00 ± 1.00^{d}	120.00 ± 1.00^{d}	39.30 ± 0.61^{c}	61.03 ± 1.00^{c}	25.41 ± 0.72^{c}	41.73 ± 2.83^{c}	2.47 ± 2.19^{a}	34.00 ± 17.87^{d}	38.90 ± 1.15^{c}	20.00 ± 2.00^{c}	5.73 ± 1.42^{a}	40.58 ± 0.40^{d}
Overall	–	67.00 ± 35.41	94.58 ± 48.14	39.83 ± 8.04	60.25 ± 7.61	34.94 ± 6.01	39.43 ± 11.19	1.79 ± 1.95	27.37 ± 11.77	40.20 ± 10.80	30.93 ± 10.60	4.02 ± 2.04	28.96 ± 15.02
F value	–	2.756	3.184	124.093	147.941	82.93	143.465	0.240	176.834	292.494	287.565	1.814	4.510
Sig@0.05 level	–	S	S	S	S	S	S	NS	S	S	S	NS	S

Mean ± standard deviation followed by same superscript letters within column is not significant, when subjected to Tukey's mean range test @ 0.05 level

S significant, *NS* not significant

[a,b,c,d] Values containing same superscripts are not significant at 0.05 level

annual income as they are working as labourers in other farmlands on daily wages and below the poverty line. Because of this, the majority of them cannot afford to buy cleaner energy sources and therefore, they depend much on easily available and economically feasible fuelwood resources.

In these four villages, firewood is the dominant source of energy for their daily requirement as present in Table 2. The villagers mainly use biomass fuel for cooking and heating purposes. The sources of energy available include fuelwood and agricultural residues, kerosene and liquid petroleum gas (LPG).

They use different types of energy sources such as firewood and agricultural residues as traditional energy types while LPG and kerosene as modern energy types. Among these energy types, the biomass energy is the one which is mainly used as the primary sources of energy. The results of the investigation show that all the households of Uppinamole village use firewood as their main energy source. Usage of LPG as energy source is relatively less in these villages. Firewood is the primary and major fuel (94.78 %) for cooking in all these villages, followed by agricultural residues (78.87 %), kerosene (55.85 %) and LPG (35.83 %). In all these villages, kerosene is also used for lighting purposes.

The trees commonly used as fuelwood in these villages are shown in Table 3. Among these, the most preferred species are *Coccus nucifera*, *Prosopis juliflora*, *Acacia auriculiformis*, *Ficus benghalensis* and *Randia uliginosa* as they can be easily grown in the farmlands. The species with higher wood density are preferred as fuel because of their high energy content per unit volume and their slow burning property [16, 17]. The villagers do not prefer to use the wood of *Pongamia pinnata* and bamboo species as they find that the cooking requires consumption of more quantity of wood. Moreover, they experienced less heat being generated by the wood of these species which also burn out rapidly. The villagers also do not prefer to use the wood of *Coccinia grandis* as it emanates bad smell during combustion.

It is established that firewood with heavy weight, less moisture and ash content gives more heat [18]. The ash content in timber is an important feature that affects the fuel capacity. High ash content makes it less desirable as fuel [19–21], because a considerable part of the volume cannot be converted into energy [22]. If the firewood is not properly dried up, it gives more smoke and less heat while burning, because it requires 3.21 MJ (Mega Joules) of energy to remove 1.0 kg of moisture present in the fuel [23]. Wood makes an outstanding fuel as it is 99 % flammable if it is completely dry [24, 25].

Gathering fuelwood involves a lot of hardship of walking for long distances and carrying head loads of

Table 2 Types of energy sources used as fuel by villagers (%)

Energy sources	Name of the villages			
	A.Devarahalli	Malarapalya	Uppinamole	Katanvadi
LPG	45.83 ± 1.04[a]	41.64 ± 0.92[a]	6.55 ± 0.08[a]	49.30 ± 0.85[a]
Kerosene	88.40 ± 0.95[b]	40.03 ± 0.26[a]	58.95 ± 1.53[b]	36.01 ± 0.61[b]
Firewood	97.43 ± 0.56[c]	97.58 ± 0.75[b]	99.34 ± 0.60[c]	84.78 ± 1.55[c]
Agricultural residues	69.52 ± 0.83[d]	87.54 ± 0.83[c]	78.83 ± 0.36[d]	79.58 ± 0.65[d]
F value	2.086	5.025	6.683	1.691
Sig @ 0.05 level	S	S	S	S

Mean ± standard deviation followed by same superscript letters within column is not significant, when subjected to Tukey's mean range test @ 0.05 level

S significant

[a,b,c,d] Values containing same superscripts are not significant at 0.05 level

Table 3 Commonly used firewood species

S. no.	Scientific name of the species	S. no.	Scientific name of the species
1	*Acacia nilotica* (Gobli)	11	*Acacia leucophloea* (Bili Jali)
2	*Ficus benghalensis* (Ala)	12	*Prosopis juliflora* (Gobli)
3	*Albizia amara* (Chujli)	13	*Albizia lebbeck* (Dodda Baage)
4	*Azadirachta indica* (Bevu)	14	*Morinda tinctoria* (Muddi)
5	*Acacia ferruginea* (Banni)	15	*Pongamia pinnata* (Honge)
6	*Ficus infectoria* (Basari)	16	*Acacia auriculiformis* (Jaali)
7	*Persea Americana* (Benne)	17	*Sapindus laurifolius* (Antuvala)
8	Randia *uliginosa* (Kare)	18	Coccinia grandis (Tonde)
9	*Mammea suriga* (Surgi)	19	*Citrus maxima* (Chakotta)
10	*Terminalia arjuna* (Matti)	20	*Anogeissus latifolia* (Bejjalu/ Dindiaga)
11	*Coccus nucifera* (coconut)	21	*Terminalia paniculata* (Matti)

Name in the parenthesis represents the local name of the species

Table 4 Time and effort involved in collection of firewood

Name of the villages	Distance travelled for collection (km)	Time spend/day for collection (h)	Firewood collection/day (kg)
A.Devarahalli	2.85 ± 0.50[a]	2.99 ± 0.10[a]	19.47 ± 0.64[a]
Malarapalya	2.54 ± 0.03[a]	3.64 ± 0.40[b]	19.00 ± 0.43[a]
Uppinamole	3.23 ± 0.09[b]	3.58 ± 0.11[b]	22.53 ± 0.47[b]
Katanvadi	2.56 ± 0.10[c]	3.68 ± 0.10[b]	21.83 ± 0.21[b]
Overall	2.79 ± 0.30	3.47 ± 0.31	20.71 ± 1.62
F value	55.77	37.57	41.97
Sig @ 0.05 level	S	S	S

Mean ± standard deviation followed by same superscript letters within column is not significant, when subjected to Tukey's mean range test @ 0.05 level

S significant

[a,b,c] Values containing same superscripts are not significant at 0.05 level

fuelwood that can cause health disorders in individuals (mostly women and children) [26]. Table 4 gives the details of efforts made and time spent in gathering of fuelwood. The average walking distance to collect fuelwood is about 2.79 km. They spend time around three and half hours to collect an average of 20.71 kg of fuelwood per day. Almost, these efforts are done by women only, as they are the ones mainly associated with gathering, processing and transportation of fuelwood. Very few people are getting the firewood from wood depots, but most of them are collecting from their own farmland, village forest and nearby natural forest. Crop residues are generally collected from their own farmland.

Fuelwood consumption with seasonal variations in the studied villages is shown in Table 5. The minimum per capita consumption of fuelwood recorded during summer season in Malarapalya and Uppinamole villages is 0.82 kg per capita per day. The consumption of fuelwood is more in the rainy season because of its usage in domestic purposes such as water heating. In all the seasons, per capita consumption of firewood is more in the Katanvadi village as compared to other villages.

The overall survey data shows that, there is a positive correlation between the household family size and the volume of firewood consumed per day (Fig. 2). A strong correlation ($R^2 = 0.99$) is found between the household size and firewood consumption in rainy season, followed by winter ($R^2 = 0.98$) and summer ($R^2 = 0.97$) seasons.

Table 5 Seasonal and per capita consumption of firewood in the villages of Yelandur

Name of the villages	Daily consumption of firewood (kg)					
	Household consumption/day			Per capita consumption/day		
	Summer	Rainy	Winter	Summer	Rainy	Winter
A.Devarahalli	3.58 ± 0.08[a]	4.81 ± 0.96[a]	4.40 ± 0.23[ab]	0.87 ± 0.06[a]	1.08 ± 0.01[a]	0.97 ± 0.02[a]
Malarapalya	3.52 ± 0.16[a]	5.05 ± 0.13[a]	4.19 ± 0.16[a]	0.82 ± 0.03[a]	1.16 ± 0.02[a]	0.94 ± 0.01[a]
Uppinamole	4.14 ± 0.11[b]	5.38 ± 0.15[b]	4.79 ± 0.90[bc]	0.82 ± 0.03[a]	1.05 ± 0.02[b]	0.96 ± 0.02[a]
Katanvadi	4.26 ± 0.14[b]	5.83 ± 0.52[b]	4.91 ± 0.08[c]	0.84 ± 0.02[a]	1.17 ± 0.02[b]	0.98 ± 0.02[a]
Overall	3.88 ± 0.36	5.27 ± 0.41	4.57 ± 0.33	0.84 ± 0.04	1.12 ± 0.06	0.96 ± 0.02
F value	27.95	44.96	14.59	1.28	43.59	2.15
Sig @ 0.05 level	S	S	NS	NS	S	NS

Mean ± standard deviation followed by same superscript letters within column is not significant, when subjected to Tukey's mean range test @ 0.05 level

S significant, *NS* not significant

[a,b,c] Values containing same superscripts are not significant at 0.05 level

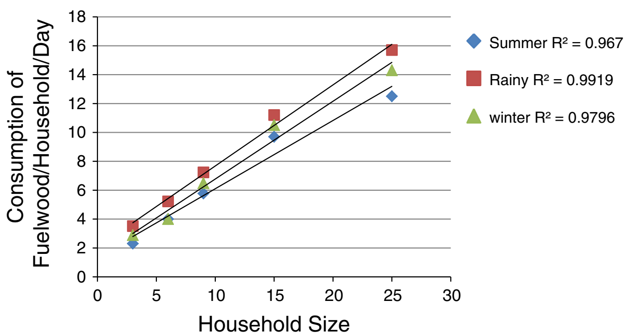

Fig. 2 Correlation coefficient between household size and fuelwood consumption in different seasons

Table 6 Household size and average firewood consumption in different seasons

Household size	Average firewood consumption/household/day (kg)		
	Summer	Rainy	Winter
1–3	2.3	3.51	2.89
4–6	3.81	5.22	4
7–9	5.77	7.23	6.48
10–15	9.7	11.2	10.5
16–25	12.3	15.7	14.3

The volume of firewood used per day varied from 2.3 to 12.3 kg in summer, 3.51–15.7 kg in rainy and 2.8–14.3 kg in winter seasons, depending on the size of the household (Table 6).

It was observed that, the households use different types of stoves for cooking as shown in Table 7. Four types of stoves (Traditional, Clay, Metal and ASTRA) are used in these villages. The majority of the households use clay stoves for biomass fuels. This kind of stoves has no chimney and consists of three bricks plastered with mud to form U shape with one side left open to feed fuel. People do not use single type of fuel, but they use multiple fuels or mixed fuels in these stoves. The use of clay stove is found to be highest in Uppinamole village (77.83 %). Only 35.73 and 37.67 % of people are using ASTRA stove for cooking purpose in Malarapalya and Katanvadi, respectively.

The usage of traditional cookstove was found to be more in A.Devarahalli (57.38 %). The traditional stove is made up of three stones, which requires more firewood. The loss of heat is more in the traditional stoves as compared to other stoves. The traditional stoves using fuelwood have low thermal efficiencies of about 14 % [4]. Metal stoves are used by less number of people. In Uppinamole village, 40.29 % of the households have separate kitchens for cooking while 15.58 % cook outside the house (Table 8). 46.37 % of the people use cookstoves without chimney and proper ventilation. On an average, 68 % of households of the other three villages possess separate kitchens for cooking. It is observed that, on an average, only 45.96 % of households have cooking stoves with chimney and good ventilation for cooking. Thus, from the above data it can be predicted that the people in these villages are more prone to firewood smoke-related health problems.

ASTRA stove is found to be beneficial for the villagers as it is helpful in minimizing the deposition of particulate matter and consumption of firewood. Although, many of them are aware of problems associated with biomass smoke, they still depend on biomass cooking stoves. However, household size, level of income and cost of cleaner energy sources are the governing factors for the households to make the choice of advanced cooking stoves. There are many other factors which determine the fuel choice, e.g. culture, social desirability and security of supply [27, 28]. During our interaction most of the people

Table 7 Type of cookstoves used by households of villages

Villages	Types of cookstoves used by households (%)			
	Traditional	Clay	Metal	ASTRA
A.Devarahalli	57.38 ± 0.74[a]	34.80 ± 0.4[a]	6.27 ± 0.25[ab]	3.43 ± 0.35[a]
Malarapalya	8.30 ± 0.26[b]	46.90 ± 1.32[b]	17.70 ± 1.23[a]	35.73 ± 0.64[b]
Uppinamole	8.60 ± 0.35[b]	77.83 ± 1.59[b]	8.67 ± 0.51[b]	10.87 ± 0.76[c]
Katanvadi	4.53 ± 0.31[c]	47.30 ± 1.25[c]	7.87 ± 0.70[c]	37.67 ± 0.83[d]
Overall	19.70 ± 22.79	51.71 ± 16.64	10.13 ± 4.70	21.93 ± 15.70
F value	9.090	671.36	136.73	2.002
Sig @ 0.05 level	S	S	S	S

Mean ± standard deviation followed by same superscript letters within column is not significant, when subjected to Tukey's mean range test @ 0.05 level

S significant

[a,b,c,d] Values containing same superscripts are not significant at 0.05 level

Table 8 Housing pattern and location of cookstoves in the households of villages

Villages	Housing pattern				Location of cookstove		
	Chimney without ventilation (%)	Chimney with ventilation (%)	No chimney and no ventilation (%)	Ventilation without chimney (%)	Outside of the house (%)	Living area (%)	Separate kitchen (%)
A.Devarahalli	3.32 ± 0.12[ab]	47.17 ± 0.25[a]	28.11 ± 0.18[a]	22.31 ± 0.36[a]	6.20 ± 0.35[a]	28.38 ± 0.36[a]	66.41 ± 0.41[a]
Malarapalya	3.14 ± 0.16[a]	53.54 ± 0.61[b]	17.41 ± 0.40[b]	19.61 ± 0.72[b]	5.54 ± 0.47[a]	33.39 ± 0.36[b]	62.51 ± 0.44[b]
Uppinamole	2.44 ± 0.41[b]	30.04 ± 0.56[c]	22.37 ± 0.33[c]	46.37 ± 0.51[c]	15.58 ± 0.50[b]	45.54 ± 0.47[c]	40.29 ± 0.25[c]
Katanvadi	13.51 ± 0.44[c]	53.10 ± 0.36[c]	13.37 ± 0.33[d]	10.44 ± 0.00[d]	8.45 ± 0.39[c]	16.44 ± 0.41[d]	76.35 ± 0.42[d]
Overall	5.60 ± 4.79	45.96 ± 9.96	20.32 ± 5.77	24.68 ± 13.87	8.94 ± 4.17	30.94 ± 10.91	61.39 ± 13.78
F value	824.86	1.665	1.191	2.874	338.402	2.651	4.590
Sig @ 0.05 level	S	S	S	S	S	S	S

Mean ± standard deviation followed by same superscript letters within column is not significant, when subjected to Tukey's mean range test @ 0.05 level

S significant

[a,b,c,d] Values containing same superscripts are not significant at 0.05 level

have expressed their willingness to shift from using the traditional stove to improved stoves, if they are provided with improved stoves.

Conclusions

The study has revealed that the firewood fuels are the dominant source of energy for cooking and heating purposes. Village forests and farmlands are the chief sources of firewood for them, which are at stake. For many households, switching away from traditional biomass is not feasible in the short term. Training and awareness to use improved stoves such as ASTRA stoves can promote the better way of using biofuel sources. The analyses show that the inertia of household cooking energy preferences is due to poverty factors such as low income, low standing of living which in most cases meant no access to external or internal cooking facilities, large households, high cooking frequency of certain meals, etc. Also there are economic, technical, social and traditional constraints to complete switching to cleaner fuels. The determination of calorific values and analysis of smoke constituents of these fuelwood species can further help in identification of suitable species for better utilization of biomass energy. Recommendation of such species to be grown in wastelands of their vicinity helps in promoting self-sustenance and can reduce the pressure on natural forests for fuelwood species.

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Conflict of interest The authors declare that they have no competing interests.

Author's contributions All authors have been involved in drafting the manuscript and approved the final manuscript.

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