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BIOMASS ENERGY CONSUMPTION AND ITS UTILIZATION PATTERN BY THE TRIBES OF BILIGIRI RANGANA (BR) HILLS, KARNATAKA, INDIA

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ABSTRACT

Biomass energy is a prime requirement for meeting the domestic needs among the rural folk of developing countries. Sources for biomass energy are mainly derived from wood, agricultural residues and cow dung cakes. This study investigated the consumption and utilization pattern of firewood species among the six tribes of Biligiri Rangana hills. Field exploration, identification and sample collections of the wood species were made. The calorific value and the ash content of the firewood species were determined. The paper examined the socio-economic status, housing pattern and type of cook stoves used by the tribes. The paper highlights the calorific value, ash content of firewood species and housing pattern of the tribes.

KEYWORDS: Biomass, Calorific Value, Chimney, Cook Stoves, Households, Ventilation

INTRODUCTION

Energy is one of the major factors which influence the economic development of any country. It is a fundamental and strategic tool even to attain the minimum quality of life. Total world energy use rises from 524 quadrillion British thermal units (Btu) in 2010 to 630 quadrillion Btu in 2020. Renewable energy and nuclear power are the world's fastest growing energy sources, each increasing by 2.5 percent per year [1].

It is estimated that forty percent of the global population relies on combustion of solid biomass fuel to fulfil some or all of their household energy needs [2]. Total primary energy consumption of biomass reached approximately 57 exajoules (EJ) in 2013 [3]. The majority of the people burn biomass in traditional, inefficient cooking structures that produce dangerous indoor air environments, resulting in several millions deaths per year [4].

Biomass energy resources vary geographically, and are not uniformly distributed [5,6]. The use of biomass energy is dependent on various factors, such as geographical location, land use patterns, preferences, cultural and social issues. Income distribution patterns also contribute to variations in biomass energy use, with poorer regions relying on traditional forms of biomass, and industrialized regions using more modern biomass energy technologies [7, 8].

Heavy reliance on biomass fuels in developing countries has raised global concerns over both environmental consequences such as forest degradation, soil erosion and the adverse health consequences of indoor air pollution generated by burning wood, animal dung or agricultural residues [9]. The impact of firewood collection on forest degradation and its relationship with rural livelihood has been largely debated, the issue receiving varying attention over time [10, 11].

Traditional biomass energy is a local energy source, which is readily available to meet the energy needs of a significant proportion of the population – particularly the poor in rural areas of the developing world. Traditional biomass energy is low cost and it does not require processing before use [12]. In India, biomass fuels dominate rural energy consumption patterns, accounting for over 80 per cent of total energy consumed. Fuel wood is the most preferred and dominant biomass source, accounting for 54 percent of biomass fuels used in India. Crop residues, agricultural biomass, and livestock dung are also being used. One of the important features of rural energy use is the dependence on locally available biomass resources [13].

Wood fuels are the world's most important form of non-fossil energy burning [14]. Fuel wood, dung cakes and crop residues still remain the primary household fuels with their share in household energy consumption well above 50% in most Asian countries [15]. Roughly 275 million poor rural people in India-27 percent of the total population depend on forests for at least part of their subsistence and cash livelihoods, which they earn from fuel wood, fodder, poles, and a range of Non-Timber Forest Products (NTFP) such as fruits, flowers and medicinal plants [16].

By 2020, the total supply of fuel wood from forests and other source is estimated to be 44.4 million metric tonnes (Ministry of Environment and Forest, Government of India). An estimated 139 million metric tonnes of fuel wood was harvested above the sustainable supply in 2006 [17].

The plant biomass can be utilized directly as a solid fuel or after its conversion into liquid biofuel, such as bioethanol or biodiesel [18]. The heating value of biomass is an indication of the energy chemically bound in it, which is converted into heat energy through a combustion process. The heating value is the most important property of a fuel which determines its energy value. The design and control of a biomass combustor depend strongly on the heating value of a biomass fuel [19].

Improved biomass technologies (IBTs) contribute to more efficient and environmentally sound use of biomass energy. Improved cook stoves, for instance, are designed to reduce heat loss, decrease indoor air pollution, increase combustion efficiency and attain a higher heat transfer [20, 21]. This helps in sustainable use and management of biomass energy sources.

The present study, therefore, was aimed at examining the household firewood consumption and its utilization pattern in BR hills, Chamrajanagar district, Karnataka.

MATERIALS AND METHODS

Study Area

Biligiri Rangana hills (BR hills), is a hill range situated in Yelandur taluk, Chamarajanagar district of south-eastern Karnataka (Figure.1). It lies in the coordinates of 77°–77°16'E, 11°47'–12°9'N, covering an area of 540 sq km. The hills are located at the eastern most edge of the Western Ghats and support diverse flora and fauna in view of the various habitat types supported. The district is known for its forest resources and has a high population of forest-dwellers. The proportion of Scheduled Tribes in this district is 11 % [22] and about 12,500 Soligas (2403 families) in 57 forest villages called Podus, are dwelling inside the Sanctuary [23,24,25]. Among these, Yarkanagadde podu, Hos podu, Muttugadagadde podu, Seegebetta podu, Kalyani podu and Manjigundi podu were investigated for assessing the biomass energy utilization.

Based on the stratified simple random sampling technique [26], households were selected for collecting data on several household parameters through door to door interview. The survey was conducted to identify and quantify the biomass fuel resource and consumption patterns. A questionnaire was designed to get the data on energy use pattern, housing characteristics, cook stoves used, types of biomass fuels, commercial fuels used for cooking and heating, sources of procurement of cooking fuel, time and effort involved in procurement. The data collected from the survey were subjected to statistical analysis using ANOVA, followed by Tukey's Honest Significant Difference (HSD) mean range test for knowing the significance at $P > 0.01$ level (Probability at less than 0.01 levels).

Determination of Calorific Value:

One gram of wood powder was oven dried to constant weight and burned in an oxygen bomb calorimeter (Model AC 350) for determining calorific value.

Determination of Percentage of Ash Content:

2 g of firewood samples was put into an oven dried moisture free crucibles, and heated up to 575 ± 25^{0} C in muffle furnace for 3 hr [27]. All analyses were done in duplicate and the results were expressed on as is basis.

$$\text{\% of Ash content} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

RESULTS AND DISCUSSIONS

The data obtained from the survey of the households revealed that, biomass is the major energy source utilized by the people for cooking and heating purposes. To meet their energy requirements, 98% households are exclusively depending on forests while the remaining households depend on both forests and farm lands. Only the households of Yarakangadde (7.41%), Muttuagada gadde (2.1%) and Seegebetta (3%) are using liquid petroleum gas (LPG) as energy source in addition to firewood.

The results show that, there is 100% utilization of firewood in all the podus except Muttugada gadde podu (98%). The usage of commercial energy sources such as kerosene (8.62%) and LPG (4.17%) for cooking is very low in these villages mainly because of low income. They use these only during an emergency need. From the results of the survey (Table-1) it is evident that firewood is the major energy source for households as compared to LPG or kerosene.

The commonly used plant species as firewood are listed in Table 2. Among these species, *Embelia ribes, Garcinia indica, Gmelina arborea, Litsea glutinosa, vitex negundo and Elaeocarpus ganitrus* are used as biomass fuel occasionally during festivals of local diety. They consider these species to be sacred and hence utilize only during such occasions. One of those species, *Elaeocarpus ganitrus*, commonly known as Rudrakshi, is a threatened species in North Eastern region of India and is declining at an alarming rate due to deforestation. Further, due to ethnic importance, nuts are collected in huge quantities from the forest floor causing depletion of its seed bank [28]. Another species *Embelia ribes*, a medicinal woody climber, belonging to Myrsinaceae, commonly known as false black pepper or vidanga is reported to be vulnerable in the Western Ghats of Tamil Nadu and Karnataka states of India and is at a lower risk in Kerala state of peninsular India [29].

The households avoid some species such as *Radermachera xylocarpa*, *Viraxylem indicum, Stereospermum personatum and Nothapodytes nimmoniana* to be utilized as they have experienced more smoke, spark and bad smell during combustion of wood.

The findings of calorific value and percentage of ash content of ten plant species are shown in Table 3. Calorific value is one of the most important parameter to assess the combustibility of fuel wood. Calorific value is defined as the amount of heat that gives when it is burnt with excess of oxygen, at a given pressure and temperature. The results of the present investigation shown that, the heating (calorific) value of the samples ranged between 3042 cal/gm and 6713 cal/gm. The highest heating value was obtained in *Meliosma pinnata* (6713cal/gm) followed by *Gmelina arborea* (6134 cal/gm), while *Ixora arboria* shows lowest heating value (3042 cal/gm). The ash content is the remaining inorganic part of wood matter that cannot be combusted.

A high ash content of a plant part makes it less desirable as fuel, because a considerable part of the volume cannot be converted into energy [30]. It is one of the important parameters which directly affect the quality of fuel. A biomass having low ash content is considered better feedstock [31, 32]. Our studies have shown that there is significant difference between the calorific value and ash content of the firewood species. By conventional criteria, this difference is considered to be extremely statistically significant (The two tailed p value is less than 0.0001). The analysis shows that among ten firewood species *Acacia catechu* has highest ash content (5.8%) followed by *Litsea glutinosa* (4.2%). *Grewia tiliifolia* has the lowest ash (1.3%) content, followed by *Cantunaregam spinosa* (1.7%), *Melotus tetracoccus* (1.8%) and *Ixora arboria* (1.95%).

The average time spent, distance travelled, quantity of firewood collection and consumption per day by the households in all the podus are shown in Table-4. The households spent 2.5 hr per day on an average to collect the firewood. The people used to travel a distance of 2.3 to 3.6 kms in search of firewood. They used to gather the fallen branches of trees. The quantity of firewood collected ranges from 19.7 kg to 25 kg per day. It is recorded that the consumption of firewood /household/day ranges from 4.42 kg to 6 kg. The results have shown that all the podus use more or less same quantity of firewood.

In our investigation it is recorded that the households are using various types of biomass cook stoves for cooking (Table 5). Traditional type of biomass cook stove require more firewood than necessary, but some studies have shown that the efficiency of a three-stone cooking stoves can be quite high if the fire is closely tended and managed [33]. While cooking in the traditional stoves, people use small and well dried wood pieces. Bembridge and Tarlton [34] reported the preference of smaller pieces of firewood by gatherers as it tends to suit the traditional method of making fires. Among the other types of cook stoves used by podus, clay stove is mostly preferred by households. Highest usage of clay stoves was seen among Yarkanagadde podu (92.59%) while it was used to a lesser extent by Manjigundi podu (13.3%). The improved cook stove ASTRA is used only by Hosa podu (6.9%), Muthugagadde (12.5%) and Sigebetta podu (8.82%).

It is reported that the ASTRA improved stove had the highest PHU (Percent heat utilization-34%), considerably higher than the traditional stove fuelled with firewood (14.2%) [35]. The concentrations of aerosol components and gases in the indoor air during the operation of improved cooking stoves (ICS) were found to be lower as compared to traditional cooking stoves (TCS) [36].

Within developed regions, nearly every solid fuel combustion system that operates within an indoor environment includes a ventilation system to transport combustion products outside of the user envelope. In underdeveloped regions this feature has been met with resistance. Many end-users prioritize stove cost and fuel savings over indoor air quality and chimneys are sometimes perceived to add cost to a stove without saving fuel [37]. Chimney is indeed capable of being advantageous or deleterious to a stove system depending on design, implementation, and maintenance [38].

The results present herein show that, the housing pattern in the villages very poor without proper ventilation and chimney etc., (Table 6). Also there are no separated kitchens for cooking among the inhabitants of Kalyani and Manjigundi podu (Table 7). The households of Manjigundi podu used to cook exclusively in living room (100%). However, some of the households of other podus use the cook stove outside their living room (3.7% to 21.43%).

Among the houses of Kalyani podu, there are no chimney and ventilation. This results in poor combustion efficiency caused by a low air to fuel ratio (i.e., reduced combustion air inflow or high fuel loads) leading to a substantial increase in particulate emissions as well as the organic carbon content of the emissions [39]. Opening the door and window in a kitchen lowered the particulate matter (PM) 1-hour concentrations between 93 and 98% compared to the closed kitchen, and the carbon monoxide (CO) 1 hour concentrations were 83 to 95% lower [40]. Chimney plays an active role in the performance of a stove by influencing the overall air-to-fuel ratio and subsequently the production of carbon monoxide [38]. People dwelling in such areas where particulate emissions and organic carbon content are more become more prone for health hazards. Small-scale combustion of biomass fuels, however, results in the emission of various pollutants including repairable particulates and carbon monoxide; unvented stoves operating in unventilated kitchens can result in pollutant concentrations that are harmful to the cook and anybody else present during the cooking period [41, 42].

The results of the present work confirm the existence of a greater dependency of the biomass energy of the rural folk of BR hills. Thirty eight arboreal species are being randomly used as fuel wood in the villages without knowing the heat efficiency. Most of the households use traditional cook stoves and cannot afford to use alternate improved cookstoves owing to poor per capita income. Poor house design and lack of awareness about indoor air pollution have become dearer for their health hazards.

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APPENDIES

Table 1: Types of Energy Sources Used as Fuel by Villagers (%)

Name of the Villages	Types of Energy Sources			Source of Firewood
	LPG	Kerosene	Firewood	Forest
Yarkanagadde	7.41	7.41	100	100
Hosa	0.00	3.45	100	96.6
Muttugadagadde	2.10	2.10	98	98
Sigebetta	3.00	23.50	100	100
Kalyani	0.00	0.00	100	92.9
Manjigundi	0.00	7.00	100	100
Mean	2.09	7.24	99.67	98.0
Variance	8.45	71.54	0.67	7.6
Std. Dev	2.91	8.46	0.82	2.76
Std. Err.	1.19	3.45	0.33	1.13
Tukey HSD Test: HSD[.05]=7.61; HSD[.01]=9.65				
LPG vs Kerosene			P > 0.01	Non- significant
LPG vs Firewood			P < 0.01	Significant
LPG vs Forest as source			P < 0.01	Significant
Kerosene vs Firewood			P < 0.01	Significant
Firewood vs Forest as source			P > 0.01	Non- significant

Table 2: Commonly Used Plant Species as Firewood

Sl.No	Name of the Species	Local Name	Family
1	*Grewia tiliifolia*	Dadsu	Tiliaceae
2	*Kydia calycina*	Bende	Malvaceae
3	*Anogeissus latifolia*	Bejjalu	Combretaceae
4	*Catunaregam spinosa*	Kaare	Rubiaceae
5	*Celtis tetrandra*	Kakkeelu	Ulmaceae
6	*Eriolaena quinquelocularis*	Katale	Sterculiaceae
7	*Bischofia javanica*	Neelalu	Euohorbiaceae
8	*Terminalia paniculata*	Holuge	Combretaceae
9	*Mitragyna parviflora*	Ettaga	Rubiaceae
10	*Phylanthus emblica*	Naayi nelli	Euohorbiaceae
11	*Ixora arboria*	Goraga	Rubiaceae
12	*Memecylon umbellatum*	Chiguri	Melastomataceae
13	*Aporusa lindleyana*	Kana anse	Euohorbiaceae
14	*Melotus tetracoccus*	Jeneraku	Euohorbiaceae
15	*Persea americana*	Benne mara	Lauraceae
16	*Acacia catechu*	Kaggali	Mimosoideae
17	*Cassia fistula*	Kakke	Fabaceae
18	*Helicteres isora*	Kowri	Sterculiaceae
19	*Bauhinia malabarica*	Kallu muttuga	Caesalpiniodeae
20	*Lantana camara*	Roja	Verbenaceae
21	*Lantana indica*	Roja	Verbenaceae
22	*Elaeocarpus tuberculatus*	Kende	Elaeocarpaceae
23	*Meliosma pinnata*	Mustaka	Sabiaceae

24	*Canarium strictum*	Dhoopa	Burseraceae
25	*Boswellia serrate*	Naadu Dhoopa	Burseraceae
26	*Trichilia connaroides*	Kari hittina mara	Meliaceae
27	*Nothapodytes nimmoniana*	Moragadi	Lcacinaceae
28	*Radermachera xylocarpa*	Udi mara	Bignoniaceae
29	*Stereospermum personatum*	Paadri	Bignoniaceae
30	*Bridelia retusa*	Sirhonne	Phyllanthaceae
31	*Diospyros melanoxylon*	Toopura	Ebenaceae
32	*Diospyros motana*	Jagala ganti	Ebenaceae
33	*Embelia ribes*	Vayu vilanga	Myrsinaceae
34	*Garcinia indica*	Punar puli	Clusiaceae
35	*Gmelina arborea*	Kooli	Verbenaceae
36	*Litsea glutinosa*	More	Lauraceae
37	*Vitex negundo*	Lakki patre	Verbenaceae
38	*Elaeocarpus ganitrus*	Rudrakshi	Erythroxylaceae

Table 3: Calorific Value and Ash Content of Firewood Species

Serial No.	Name of the Species	Calorific Value (cal/gm)	Normalized Data for cal/gm (%)	Ash (%)
1	*Grewia tiliifolia*	5172	9.90	1.30
2	*Cantunaregam spinosa*	5908	11.29	1.70
3	*Ixora arboria*	3042	5.80	1.95
4	*Mallotus tetracoccus*	5071	9.69	1.80
5	*Acacia catechu*	4986	9.53	5.80
6	*Cassia fistula*	4897	9.36	3.05
7	*Meliosma pinnata*	6713	12.83	2.30
8	*Nathapodytes nimmoniana*	5348	10.22	2.10
9	*Gmelina arborea*	6134	11.72	2.33
10	*Litsea glutinosa*	5071	9..69	4.20

NOTE: The two tailed p value is less than 0.0001.

Table 4: Time and Effort Involved in Collection of Firewood by Tribes

Name of the Villages	Distance Travelled (km)	Time Spent /collection (hr)	Firewood Collection/Day (kg)	Firewood Consumption/ Household/Day (in kg)
Yarkanagadde	3.60	3.63	25.0	4.42
Hosa	2.80	1.93	19.70	4.67
Muttugadagadde	2.89	2.26	19.80	4.58
Sigebetta	2.20	2.32	22.20	5.17
Kalyani	2.80	2.36	19.60	6.0
Manjigundi	3.30	2.53	21.70	4.67
Mean	2.93	2.51	21.33	4.93
Variance	0.19	0.29	3.73	0.29
Std. Dev.	0.44	0.53	1.93	0.54
Std. Err.	0.17	0.20	0.73	0.20
Tukey HSD Test: HSD[.05]=1.56; HSD[.01]=1.97				
Distance travelled vs Time spent/ Collection			P > 0.01	Non- significant
Distance travelled vs Firewood collection/day			P < 0.01	Significant
Distance travelled vs Firewood consumption/ household/day			P < 0.01	Significant
Time spent/ Collection vs Firewood collection/day			P < 0.01	Significant

Time spent/ Collection vs Firewood consumption/ household/day	P < 0.01	Significant
Firewood collection/day vs Firewood consumption/ household/day	P < 0.01	Significant

Table 5: Type of Stoves used by Households of Villages for Cooking

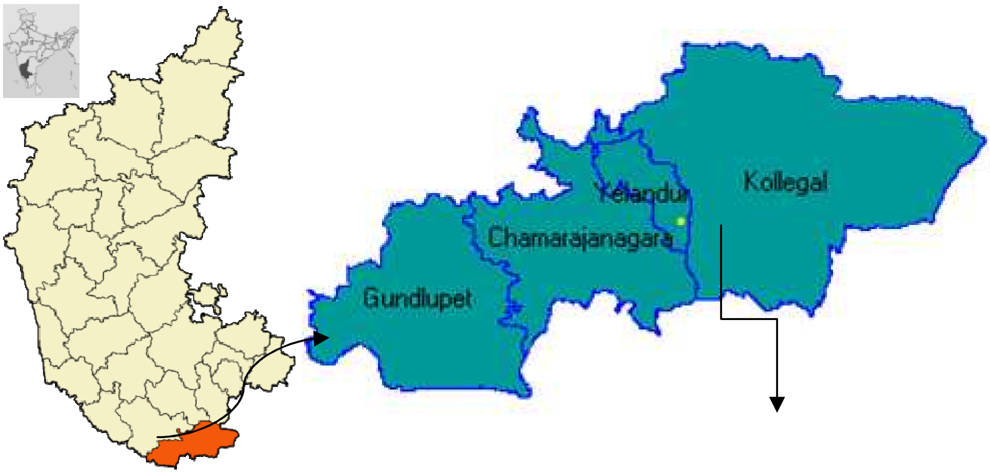
Name of the Villages	Types of Cookstoves Used by the Households (%)			
	Traditional	Metal	Clay	Astra
Yarkanagadde	14.80	3.70	92.59	0.00
Hosa	17.24	3.45	72.40	6.90
Muttugadagadde	58.30	2.10	25.00	12.50
Sigebetta	58.82	2.94	29.41	8.82
Kalyani	78.57	0.00	21.42	0.00
Manjigundi	86.66	0.00	13.30	0.00
Mean	52.40	2.03	42.35	4.70
Variance	916.93	2.78	1035.5	29.78
Std. Dev.	30.28	1.67	32.18	5.46
Std. Err.	12.36	0.68	13.14	2.23
Tukey HSD Test: HSD[.05]=36.1; HSD[.01]=45.75				
Traditional stove vs Metal stove			P < 0.01	Significant
Traditional stove vs Clay stove			P > 0.01	Non- significant
Traditional stove vs Astra stove			P < 0.01	Significant
Metal stove vs clay stove			P < 0.05	Significant
Metal stove vs Astra stove			P > 0.01	Non-significant
Clay stove vs Astra stove			P < 0.05	Significant

Table 6: Housing Pattern in the Households of B.R. Hills

Name of Villages	Housing Pattern			
	Chimney without Ventilation (%)	Chimney with Ventilation (%)	No Chimney and no Ventilation (%)	Ventilation without Chimney (%)
Yarkanagadde	7.40	29.63	33.33	29.63
Hosa	0.00	6.89	37.93	55.17
Muttugadagadde	0.00	12.70	53.19	34.04
Sigebetta	0.00	11.76	85.29	2.94
Kalyani	0.00	0.00	100	0.00
Manjigundi	0.00	0.00	93.33	6.67
Mean	1.23	10.16	67.18	21.41
Variance	9.13	121.05	857.21	476.72
Std. Dev.	3.02	11.00	29.28	21.83
Std. Err.	1.23	4.49	11.95	8.914
Tukey HSD Test: HSD[.05]=31; HSD[.01]=39.29				
Chimney without ventilation vs Chimney with ventilation			P > 0.01	Non- significant
Chimney without ventilation vs No chimney and no ventilation			P < 0.01	Significant
Chimney without ventilation vs Ventilation without chimney			P >0.01	Non- significant
Chimney with ventilation vs No chimney and no ventilation			P < 0.05	Significant
Chimney with ventilation vs Ventilation without chimney			P > 0.01	Non-significant
No chimney and no ventilation vs Ventilation without chimney			P < 0.05	Significant

Table 7: Location of Cook Stoves in the Households of B.R. Hills

Name of Villages	Location of Cook Stove		
	Outside of the House (%)	Living Area (%)	Separate Kitchen (%)
Yarkanagadde	3.70	59.25	37.03
Hosa	17.24	72.41	10.34
Muttugadagadde	10.42	77.08	12.50
Sigebetta	2.94	79.41	17.64
Kalyani	21.43	78.57	0.00
Manjigundi	0.00	100	0.00
Mean	9.29	77.79	12.92
Variance	73.95	173.94	188.85
Std. Dev.	8.60	13.74	34.31
Std. Err.	3.51	5.384	5.61
Tukey HSD Test: HSD[.05]=31; HSD[.01]=39.29			
Outside of the house vs Living area		P < 0.01	Significant
Outside of the house vs Separate kitchen		P > 0.01	Non- significant
Living area vs Separate kitchen		P < 0.01	Significant



Karnataka **Chamarajanagar District** **B.R. Hills**

Figure 1: Study Area