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Domestic Biomass Fuel Consumption Pattern in Northern Part of Bangladesh

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Abstract: Biomass fuel are considered as raw source of household fuel in rural Bangladesh. Multistage random sampling with semi-structured questionnaire was adopted to conduct this study in Lalmonirhat District, Northern part of Bangladesh. Based on income, respondents were classified into rich, middle and poor categories and a total of 150 households were selected randomly. The study were desinged to know the biomass fuel generation, consumption pattern and their associated health risk. The results revealed that 99% respondents used branches of trees as biomass fuel followed by leaves (89%), stems (72%), bamboos (67%), agricultural residues (60%) and LPG (15%) for domestic purposes. 85% respondents used *azadirachta indica* as most preferred fuelwood among which market and homestead sources contributed 61% and 39%, respectively. Other available fuelwood species were *mangifera indica* (81%), *bambusa spp.* (81%), *eucalyptus globules* (75%), *artocarpus heterophyllus* (41%), *swietenia mahagoni* (27%), *syzygium cumini* (20%) and *psidium guajava* (11%). The sources of these fuelwood contributed by homestead:market were 69:25, 60:9, 25:40, 41:6, 24:5, 3:7 and 17:15, respectively. Monthly electricity consumption of rich:middle:poor were 117:106:65 followed by kerosene (1.5:1.6:2.6), LPG (1.2:0.9:0) and candle (11:7:7). 100% respondents believed that CO_2 emitted from biomass fuel burning followed by SO_x (92%), NO_x (87%), CO (35%) and SPM (11%). The consequences of emitted pollutants might be the cause of respiratory diseases (99%) followed by rapid breathing (95%), asthma (57%), tuberculosis (16%) and lung cancer (16%). Formulation of an appropriate policy could perform an important tool to ensure efficient consumption of biomass fuel in rural Bangladesh.

Keywords: Consumption pattern, fuelwood, health risk, sustainable consumption.

INTRODUCTION

Biomass energy characterized as any material of plant or creature of woody and non-woody biomass and human excretion. This type of energy is additionally considered as sustainable power sources having the limit of decreasing temperature alteration being a part of the carbon impartial frameworks and upholding for the advancement of all-inclusive energy **[1].** Biomass energy are advancing universally to decrease ozone-harming substance CO_2 emanation by substituting petroleum products for warmth and power age **[2].** The transformation procedures of biomass energy required handling stages like cleaning, blending, drying or dandifying and this procedure generates strong fluid or vaporous fuel **[3].**

Biomass energy is very important source of energy for rural community of Bangladesh as a form of traditional fuels mainly used for domestic consumption. It is broadly categorized into wood residues, agricultural residues, animal residues and municipal solid waste **[1,4,5].** In rural Bangladesh, biomass fuel meets about 76% of total fuel demand of which 74% are collected from homestead and agriculture sources **[1].** Energy consumption pattern of disregarded villages of Bangladesh indicates 92% households used biomass fuel as their energy where wood and agricultural residues constitutes 40% of total energy consumption **[3].** Worldwide biomass consumption is eight times greater than other forms of energy contributed to around 10-14% of total energy supply. It has reducing capacity of global warming as renewable energy source and acts as a carbon neutral component of substituting fossil fuels for heat and electricity generation **[1,2].** Biomass fuel reducing the anthropogenic greenhouse gas emissions having negligible amount of sulfur, nitrogen and ash. It is also lowering the emission of NO_x, SO_x and soot than conventional fossil fuels. Rational and responsible use of biomass decline the rural poverty as it is locally available, having no dependency on the price fluctuations and supply uncertainties. Generation and utilization composition of biomass also differs from household size, social and economic status, village to village, region to region, and even country to country. Different aspects of biomass

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fuel use in Bangladesh have been studied by different researchers. Kennes et al. **[6]** conducted a research on household energy consumption pattern in Bangladesh. Sarkar et al. **[7]** surveyed research on rural energy and its utilization in Bangladesh. Akhter et al. **[8]** studied the homestead biomass fuels energy situation of a forest rich district Cox's Bazar. Miah et al. **[9]** investigated biomass fuels use by the rural households at four villages of Hathazari upazila of Chittagong region. Jashimuddin et al. **[4]** investigated the preference and consumption pattern of biomass fuels in four villages of Sandwip and Noakhali Sadar upazila of southern coastal region. Akther et al. **[1]** conducted a survey on domestic use of biomass fuels in eight villages in Raipura upazila of central region. Miah et al. **[10]** studied on the rural household energy consumption pattern in disregarded villages at Chandanaish upazila of Chittagong region. Hassan et al. **[11]** analyzed on the assessment of bioenergy potential from major crop residues and wood fuels in Bangladesh. Miah et al. **[12]** studied the domestic energy-use pattern by the households: A comparison between rural and semi-urban areas of Noakhali in Bangladesh. Hasan et al. **[13]** studied an analysis of cross-sectional variation in energy consumption pattern at the household level in disregarded rural Bangladesh. Hasan et al. **[14]** investigaterd the rural households' preferences and attitudes towards biomass fuels - results from a comprehensive field survey in Bangladesh. To the best of our knowledge, the studies have been conducted on the consumption pattern and preference of various biomass fuels using by the disregarded villagers of northern region in Bangladesh are scarced. Therefore, present study aimed to assess the status, sources, consumption pattern, preferences and their associated health risk of biomass fuel in disregarded villages at Northern Part of Bangladesh. The result will help the policy makers to formulate biomass energy policy for disregarded rural villages of Bangladesh.

MATERIALS AND METHODS

Area selection

The study area was located in Aditmari Upazila under Lalmonirhat District, in the northern region of Bangladesh and most of the communities were directly dependent on agricultural practices. The main livelihood income source in the study area was agriculture. It is located in between 25°51' - 26°03'N latitudes and 89°17' - 89°28'E longitudes, with an area of 195.03 km^2. It is surrounded by Gangacharand Lalmonirhat Sadar upazilas on the south, West Bengal on the north, Lalmonirhat sadar upazila on the east, Kaliganj upazila on the west **[15]** . There were 8 unions under the upazila and among them 3 unions (Saptibari, Sarpukur, Bhadai) were randomly selected to conduct the study. Peoples were largely depends on biomass fuelwood here as domestic purposes because these area were situated far from access to natural gas and limited supply of electricity.

Sample size

Aditmari Upazilla was purposively selected for the present study and Saptibari, Sarpukur and Bhadai Unions were selected randomly. A total of 150 respondents (50 from each union) were randomly selected and the respondents were categorized into three groups according to their monthly income (BDT) level such as rich (>15000), medium (10000-15000) and poor (<10000). The respondents were the head of the households in between 30-60 year ages.

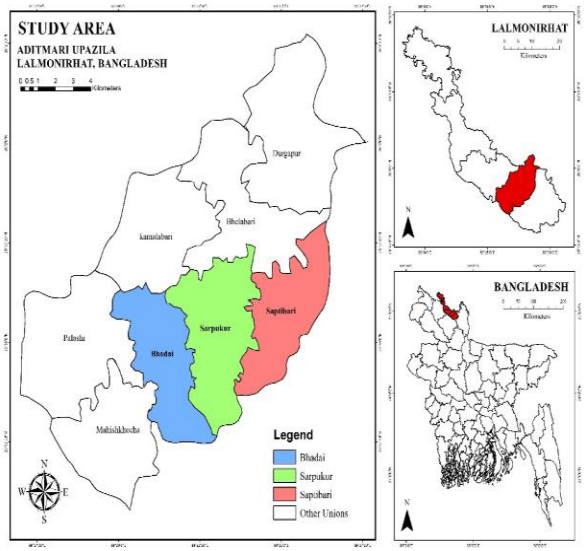

Figure 1: Map of the study area

Data collection

A semi structured self-exploratory questionnaire was developed to conduct the survey of three unions under Aditmari upazila in Lalmonirhat district. A questionnaire survey was conducted among the households to find out the desire result. Data and relevant information about the consumption pattern and preference of biomass fuel and pollutants from burning biomass fuel and associated health risk to the peoples were collected through interview of the individual households. Observation was an important phase during primary data collection. Secondary data were collected from existing publications, journals, articles, reports, websites and different government organizations sources. The collected data were analyzed by using MS Excel software and maps were produced by Arc GIS (version 10.3) software.

RESULT AND DISCUSSION

Varieties of biomass fuel

Biomass fuel is used for multi-various purposes. Cooking, paddy parboiling and water heating were major domestic activities for energy consumption. To fulfill the purposes they use various types of biomass fuel like, branches of trees, leaves of trees, stem of trees, rhizomes of bamboo, animal dung, LPG, agricultural residues (paddy straw, paddy husk and corn straw) etc. Among these, branches of trees (99%) were the major source of fuel consumed by households. Leaves of trees (89%) occupied the second largest position followed by stem of trees (72%), rhizomes of bamboo (67%), agricultural residues (60%), animal dung (57%) and LPG (15%) (figure 2). Maximum respondents used branches of trees because they collect those from homestead forest and leaves of trees were available in the villages. Small households were poor, they did not have enough financial ability to buy fuelwood so they had to collect the fuelwood from nearby homestead to meet their demand. Although LPG is comfortable and easy to cooking and other domestic activities, only 15% medium and rich respondents consumed it.

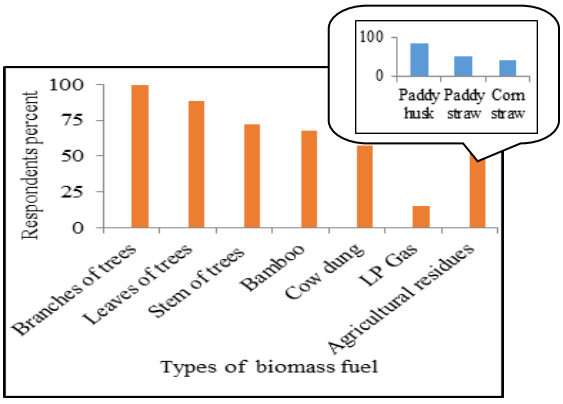

Figure 2: Different types of biomass fuel (%) used by various households in the study area

Species used as biomass fuelwood

Different types of species were found which used as biomass fuelwood for multiple domestic purposes. Among those species peoples in the study area were commonly used *Azadirachta indica* (85%), *Mangifera indica* (81%), *Bambusa spp*. (81%), *Eucalyptus globules* (75%), *Artocarpus heterophyllus* (41%), *Swietenia mahagoni* (27%), *Syzygium cumini* (20%) and *Psidium guajava* (11%) (figure 3).

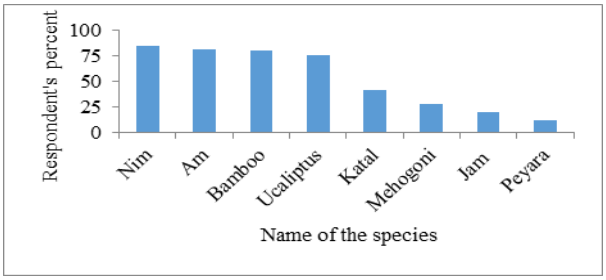

Figure 3: Commonly used fuel wood species

The respondents of the study area collected *Mangifera indica, Bambusa spp., Eucalyptus globules, Artocarpus heterophyllus, Swietenia mahagoni, Syzygium cumini* and *Psidium guajava* from both homestead and market sources.The homestead:market source of this fuelwoods were 69:25, 60:9, 25:40, 41:6, 24:5, 3:7 and 17:15, respectively (figure 4). Though the wood of *Artocarpus heterophyllus* and *Mangifera indica* were valuable and used as furniture making purposes, these were consumed largely by the local respondents due to availability in the study area. The wood of *Azadirachta indica* and *Eucalyptus globules* were so costly and also used as furniture making purposes, local peoples totally sell those species to the wood businessmen and the businessmen also resell the waste of these species without wood and local people purchased it from market.

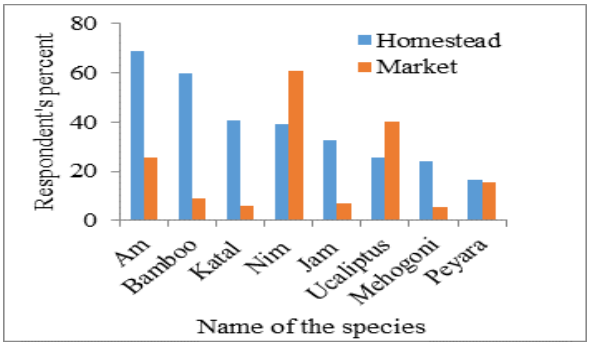

Figure 4: **S**ources of fuelwood species by respondents percent

Preference of fuelwood species

Preference is mainly dependent on the availability of biomass energy sources. It also depends on monthly income as well as social status of the respondents. The ratio of energy needed from wood rich: Medium: poor was 55: 26: 51. They collect those from both homestead and market. *Azadirachta indica* (99%) was the first preferred species by the respondents, followed by *Eucalyptus globules* (82%), *Bambusa spp*. (79%), *Artocarpus heterophyllus* (41%), *Mangifera indica* (25%), and *Swietenia mahagoni* (19%) (figure 5).

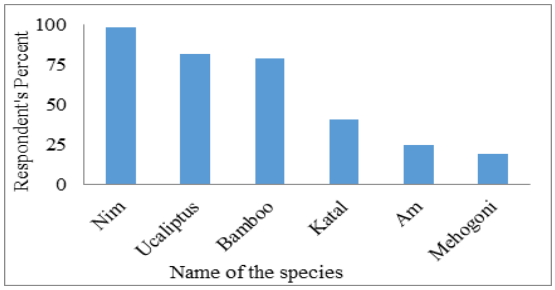

Figure 5: Preferred fuel wood species

Availability, cost and comfort ability of use (long time burn, less smoke, less sparking etc.) were important factor to the householder's preference of different categories. *Azadirachta indica* (99%) and *Eucalyptus globules* (82%) were most preferred by the respondents as fuelwood because of availability, long time burn and less smoke emission followed by *Bambusa spp.* (79%) as the third preferred to the local people due to availability and low cost. *Swietenia mahagoni (*19%) was preferred as biomass fuelwood due high cost and unavailability in the study area. These were used as mainly furniture making and other important purposes.

Pattern of domestic biomass fuel used different purposes

Energy consumption for domestic purposes, the maximum households relies on agricultural resources (paddy husk, paddy straw, corn straw etc.), trees residues (branches of trees, leaves of trees etc.) and animal dung were available in this area. The percentage of the consumers of biomass fuel energy for cooking from tree residues (100%), agricultural residues (99%) and animal dung (55%), respectively (figure 6).

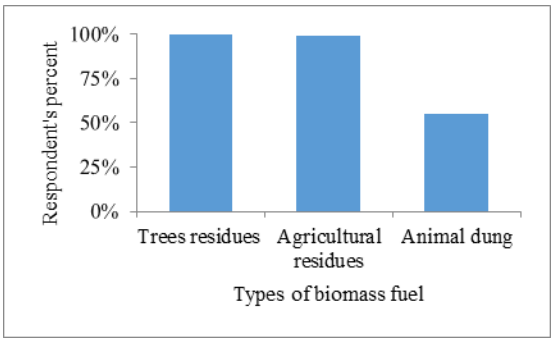

Figure 6: Biomass energy consumption pattern for domestic purposes

People of poor and medium class households made dung cake in dry season and preserve it for using as a fuel for cooking purpose in the rainy season because this period, wood, agricultural crop residues, leaves and twigs were damp and unavailable and householders were unable to collect it. Using status of biomass fuel in different classes of households were categorized into four types (≤200 kg, 201-250 kg, 251-300 kg and >300 kg) depending on weight of biomass fuel. In the ranges of ≤200 kg (rich households 40%, medium households 22%, poor households 16% and average 26%) used biomass fuel followed by 201-250 kg (rich 20%, medium 34%, poor 42% and average 32%), 251-300 kg (rich 20%, medium 28%, poor 18% and average 22%), and >300 kg (rich 20%, medium 16%, poor 24% and average 20%) used biomass fuel per month (figure 7).

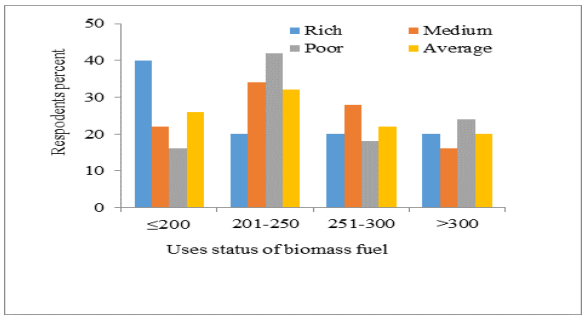

Figure 7: Using status of biomass fuel by different classes of household's

The result revealed that ≤200 kg in the rich households were highest (40%) because the family members of the rich households were less compare to the poor and also used LPG cylinder for temporary in emergency activities (heating water for making tea and coffee, heating milk etc.). 201-250 kg range, the poor households were highest (42%) due to their large family size and don't use LPG and the medium households were about 34% because they had the large family and sometimes use biomass fuel for paddy parboiling. And in the range of >300 kg poor households were more compare to the others about 24% because some poor families use biomass fuel for cooking purposes besides other domestic purposes like paddy parboiling etc. Although maximum poor, they consumed more energy because some poor households were used biomass fuel for cooking and other domestic purposes like paddy parboiling.

Consumption of non-renewable energy

For daily domestic energy demands, most of the respondents used at least two varieties of non-renewable fuel. In this study, electricity (75%) and kerosene (82%) were found as major energy sources for lighting followed by candles (19%) and LPG (6%). Hassan et al. **[13]** conducted research on biomass fuels considering different regions of Bangladesh and the studied results were 56%, 98%, 10% and 4%,

respectively. The difference of the results might be associated with rural electrification and respondent preference. Rich (88%) and middle (82%) categories respondent prefer to use electricity as main source of non-renewable energy whereas 90% poor category respondents used kerosene. Monthly consumption of electricity among the non-renewable energy rich: medium: poor were 117.05:106.59:65.18 followed by kerosene oil 1.49:1.65:2.64, LPG 12:9:0, candle 11.25:6.67:6.74, respectively (table 1). These results showed that rich respondent group monthly energy consumption ratio was higher than other two groups. But candles consumption was significantly higher in rich groups because of frequently load shedding. On the other hand, kerosene consumption was highest and LPG was zero for poor respondent group because of their low income followed by the medium and rich groups.

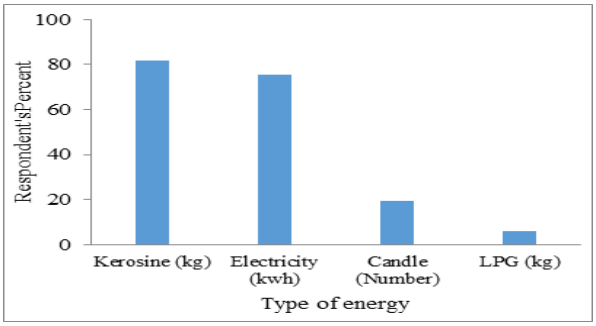

Figure 8: Consumption status of non-renewable energy by the respondents

Table 1: Consumption pattern of non-renewable energy among different groups of households and per households (* indicates per month and ** indicates per year)

Non-renewable energy	Households (HH)					
	Rich	Per HH*	Medium	Per HH*	Poor	Per HH*
Electricity (kwh)	5150	117.05	4370	106.59	1825	65.18
Kerosene oil (kg)	55	1.49	67.5	1.65	119	2.64
LPG (cylinder)	54	12**	36	9**	0	0
Candle (number)	45	11.25	40	6.67	128	6.74
Total	5304	138.79	4513.5	126.89	2072	74.56

Diseases associated with biomass fuel burning for domestic purposes

Incomplete combustion of fuelwood leads to emit of tiny particles with other components that may be cause of damaging human health **[16]** . Both rural and urban young children and poor women were high health risk because they were mostly present during cooking. For this, they were suffered from various types of diverse diseases called respiratory and cardiac problem **[17]** . Young children living in households were 2/3 times greater respiratory risk compared to those households using LPG or cleaner fuels **[18]** . As the study area was also a disregarded and maximum peoples were directly dependent on agricultural activities so they used largely biomass fuel as domestic purposes. Due to the rapidly used of biomass fuel the peoples of these area were largely affected by some disease like respiratory problems, tuberculosis, asthma, lung cancer, rapid breathing etc. From the selected respondent's maximum were posed respiratory problem and rapid breathing diseases caused by biomass fuel burning accordingly about 99% and 95% (figure 9). On the other hand, asthma, tuberculosis and lung cancer diseases were posed by 57%, 16% and 16% respondents and they also posed that respiratory, rapid breathing and asthma were largely affected by the women, children(less than 5 years) and adult person who's were stayed long time in the surrounding of the cooking room. And about other diseases, posed maximum male person and they largely affected by those diseases due to cigarettes smoking and others.

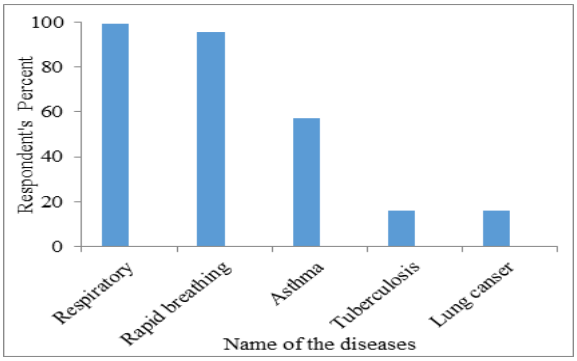

Figure 9: Respondents (%) affected by different disease

Pollutants from biomass fuel burning

Smoke are important source of indoor air pollution that creates from biomass fuel combustion had adversely affect human health by SPM and other gaseous pollutants like CO, CO_2, SO_2, NO_2 etc **[19]**. During the burning of biomass fuel for domestic purposes a large amount of pollutants are emitted. These pollutants were very harmful for both human health and environment. Among the respondents, 100% posed that CO_2 emitted from biomass burning, followed by SO_2 (92%), NO_2 (87%), CO (35%) and SPM (11%) respectively.

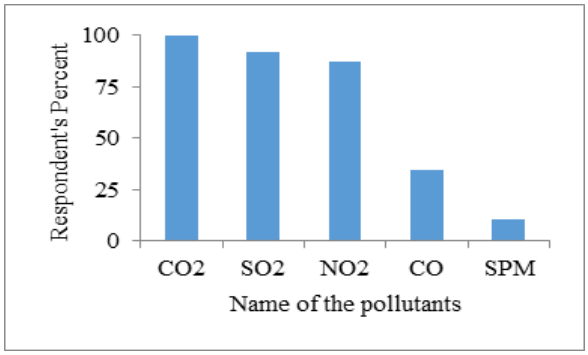

Figure 10: Pollutants emission from biomass fuel burning by respondent's perception

People's perception on biomass energy policy formulation

Biomass energy is derived from wood and waste. It generates electricity as well as produce heat. It has more advantages than fossil fuels and also helps to reduce carbon emissions as well as other greenhouse gas emissions that influences global warming that results to change the world's climate. As biomass is linked with a certain amount of different types of emissions but this is negligible compared to present energy sources or other fossil fuels. The plants absorbed the carbon di oxide for growing up which is has gone back to the atmosphere but the CO_2 emits from fossil fuels go back to atmosphere. The main causes of global warming were the greenhouse gas emissions but it should be noted that CO_2 and SO_2 with toxic gases were produced during biomass fuel burning. Biomass can help to clean up our natural environment but it influences the environment globally.

From the above discussion we clearly understood the benefits of biomass fuel. So, Renewable Energy Policy of Bangladesh 2008 has got some specific guidelines for Renewable Energy Technologies and set a number of objectives to conserve the biomass. The study revealed that 100% respondents posed that policy is needed to conserve the biomass. Among the total respondents about 91% were posed that policy helps to ensure sustainable use of biomass energy each level, 53% posed that it helps to facilitate public-private partnership sectoral investment projects, 23% posed to increase contributions of electricity generation from renewable energy sources, 26% posed that develop local technology, 47% posed that facilitate more energy usage in each level, 84% posed that aware the public for minimize use of biomass energy and 97% posed that it helps to aware about over extraction of burning fuel wood. It also showed that the highest perception of peoples to aware about over extraction of burning fuelwood and second is to ensure sustainable use of biomass energy. The research concluded that all the perception are essential, so government and others authority should be taken necessary steps to improve the energy policy to ensure conserve the biomass at every level.

DISCUSSION

The research provides an overview of biomass energy consumption pattern and preferences at the household level in Nothern Region of rural Bangladesh. The study method was similar to previous studies **[1,10,13]**. It was observed after the field investigation that the respondents were not always consider the moisture level of the fuels for estimation their consumption. Therefore, the estimation may not always be accurate but it provided an approximation. Monthly fuelwood consumption in the study was 254 kg per household. This result was consistent with previous studies such as Asaduzzaman and Latif **[20]** 244 kg; LGED and FAO **[21]** 214 kg; Akther et al. **[1]** 665 kg without considering the moisture content; Miah et al. **[10]** 66 kg and Hassan et al. **[13]** 219 kg per household. Hassan et al. **[13]** reported that homestead was main fuel source in rural Bangladesh. Our study results was inlined with their findings that homestead sources of fuelfwood species were *Mangifera indica* (69%), *Bambusa spp.* (60)%, *Eucalyptus globules* (25%), *Artocarpus heterophyllus* (41%), *Swietenia mahagoni* (24%), *Psidium guajava* (17%) and *Syzygium cumini* (3%). Low income respondents used rice straw, leaves and twigs, and cow dung. This type of trends was also observed by previous research **[1,10,13]**. Kerosene and electricity were the main non-renewable fuels in rural Bangladesh **[22]**. Our results revealed that 75% household lighting energy derived from electricity, 82% from kerosene and 19% from candle. Asaduzzaman and Latif **[20]** claimed average monthly consumption of electricity, kerosene and candle were 12 kWh, 2.42 L and 0.04 kg per household respectively while Miah et al. **[10]** found 47.89 kWh, 1.81L, and 0.21 kg, respectively. But our present study showed that monthly consumption of electricity among the non-renewable energy in different categories respondent were rich 117.05 kWh, middle 106.59 kWh, poor 65.18 kWh, respectively followed by kerosene oil 1.49 kg, 1.65 kg, 2.64 kg and candle 11.25, 6.67, 6.74 pieces, respectively. Long-term research on biomass energy is important as it could offer new possibilities to shift from the current inefficient consumption pattern of biomass-based fuels to a more efficient.

CONCLUSION

To meet the future energy demand in the rural area of Bangladesh, biomass is considered as the growing renewable resource. The present study was conducted in a disregarded area in the northern region of

Bangladesh where the households were largely depended on biomass fuel for their domestic activities. Though natural gas was not available, leaves of trees, bamboo, stems, branches and twigs, different agricultural residues and cow dung were found as energy sources in the study area. Market, homestead and agricultural fields are playing important role to supply the biomass fuel. Electricity, candle, LPG and kerosene oil are used as non-renewable sources and among these kerosene was prominently used for lighting purposes. All categories of households with access to electricity used candles and kerosene lamps when load shedding occurred; however, the rich respondents preferred to use candles instead of kerosene. Combustion of biomass fuel produces SPM, CO, CO_2, SO_2, NO_2, etc. Thus, it has a negative impact on both environment and human health and creates different types of disease for respondents. The findings of this study can utilize by policy makers to formulate biomass energy policy for ensuring the efficient use of biomass fuel at rural areas in Bangladesh.

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CONFLICT OF INTEREST

The authors declared that there is no conflict of interest.

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Supplementary Data

Appendix 1: Commonly found fuelwood species in the study area

Serial No.	Local name	Scientific name
1.	Mango/Am	*Mangifera indica*
2.	Boroi	*Ziziphusm aurutiana*
3.	Bamboo	*Bambusa spp*
4.	Bot koroi	*Samaneas aman*
5.	Jam	*Syzygium cumini*
6.	Shimul	*Bombax ceiba*
7.	Kadam	*Anthocephalus chinensis*
8.	Mahagonia	*Swietenia mahagoni*
9.	Coconut	*Cocos nucifera*
10.	Peyara	*Psidium guajava*
11.	Eucalyputs	*Eucalyptus globules*
12.	Nim	*Azadirachta indica*
13	Kanthal	*Artocarpus heterophylus*