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A Comparative Study on Biomass Fuel Consumption, Collection and Preference Patterns by Rural Households of Forest and Non-Forest Areas in Northern Bangladesh

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ABSTRACT

Biomass fuel is the most important form of renewable energy in many parts of the world including Bangladesh. Its extraction is considered as a leading cause of forest degradation of developing countries like Bangladesh. Its consumption, collection and preference patterns are thus very important indicators of overexploitation of forest. On the other hand, forests are meager in mainly northern region of Bangladesh. Reliable data and information are scanty on biomass fuel in Bangladesh, particularly in formulating its proper management plan. The aim of this study was to conduct a comparative study on the aforesaid patterns in forest and non-forest areas of northern region of Bangladesh. The study was carried out by adaptive multistage random sampling technique. A total of 90 households (45 from forest area, 45 from non-forest area) were selected randomly and based on the monthly income the households were categorized into rich, medium, poor groups. The consumption of biomass fuel was found to be differed significantly between forest (2.10 kg/capita/day) and non-forest (1.71 kg/capita/day) area. Forest, market, agriculture, homestead and roadside plantation were identified as sources of biomass fuel, and the contribution of each sources varied significantly between the areas except market. In forest area, maximum amount of biomass fuel was collected from nearby forests (44%) and poor households collected 78% of biomass fuels from the same sources. In non-forest area, roadside plantation (31%) and homesteads (24%) were the major sources of biomass fuel, and poor households collected biomass fuel mainly from roadside plantations (75%). Stems, branches, leaves, agricultural residues and cow dung were used as biomass fuel in both areas but the consumption of each biomass fuel types varied significantly except leaves. Women were identified as major biomass fuel collector and most of the biomass fuel was found to be collected during morning to noon in both areas. Most commonly used fuelwood species was *Shorea robusta* in forest area and *Eucalyptus camaldulensis* in non-forest area. The findings of this study will help policymakers to take steps in halting deforestation as well as meeting the villager's needs for biomass fuel.

Keywords: Bangladesh, biomass fuel, forest degradation, fuelwood, homesteads, natural forests

INTRODUCTION

Biomass, the total of non-fossil organic materials that have intrinsic chemical energy content, derived from carbon based materials and mainly comprised of agricultural residues, animal manures, agro-industrial residues, municipal solid wastes and harvests from forests (Balat & Ayar, 2005; Hossain & Charpentier, 2015). Biomass energy is the largest source of renewable energy representing 77.78% of renewable global energy supply and 10% of global primary energy supply (WEC, 2016). Biomass fuel is the most potential indigenous source of energy and provides almost 35% of primary energy demand in developing countries (Balat, 2006; Demirbas, 2006). In some developing countries, it accounts for more than 90% of total rural energy source (Demirbas & Demirbas, 2007). It is still the main energy source in many developing countries (e.g. Nepal 97%, Bhutan 86%, Africa 39%) and mainly fuelwood is used as bio-energy in those countries for cooking and heating (Hoogwijk *et al.*, 2005).

Bangladesh is one of the most densely populated country in the world with 161.38 million people (WPP, 2019). Traditional biomass fuels are predominant sources of rural energy to meet cooking, commercial, and industrial needs in Bangladesh, mainly in the form of agricultural residues (46%), wood wastes (34%), and animal dung (20%) (Rahman *et al.*, 2013; Huda *et al.*, 2014; Islam *et al.*, 2014). Homestead, agriculture and plantation are main sources of biomass fuel and about 76% of rural fuel demand is supplied by biomass of which 74% are collected from agriculture and homestead (Akther *et al.*, 2010). The collection of biomass fuel is unsustainable (Hassan *et al.*, 2012) and overexploitation of natural and homestead forests is potentially sharing deforestation and day by day the shortage intensity is being increased across the country (Akther *et al.*, 2010).

The extraction and utilization of biomass fuel depend on demographic and socio-economic factors of households and varies from village to village, region to region and country to country. In Bangladesh, different aspects of biomass fuel have been studied by various researchers. Kennes *et al.* (1984) assessed the quantitative description of biomass energy situation by various socio-economic groups of Bangladesh. Bari *et al.* (1998) studied the biomass energy supply and use at village levels using three methods in Mymensingh and Kishoreganj district. Miah *et al.* (2003) assessed biomass fuel used by the rural households in Chittagong region. Jashimuddin *et al.* (2006) investigated the consumption of biomass fuel and preference pattern in disregarded villages of Sandwip and Noakhali Sadar upazila. Miah *et al.* (2010) investigated the consumption of energy by rural households in disregarded villages of Chandanaish upazila of Chittagong district. Miah *et al.* (2011) compared domestic energy use pattern of rural and semi-urban area of Noakhali district. Chowdhury *et al.* (2011) described biomass fuel use and burning techniques by forest user groups of Rema kalenga Wildlife Sanctuary. Halder *et al.* (2014) conducted research on the resources of biomass energy and practices of related technologies in Bangladesh. Baul *et al.* (2018) compared energy consumption and related emission from renewable (biomass) and non-renewable sources in Bangladesh. Alam *et al* (2019) investigated biomass fuel consumption pattern at household level in northern region of Bangladesh. But no comparative study on biomass fuel situation of forest and non-forest sources were carried out. There is a lack of reliable information on biomass fuel to meet up its demand-supply gap. Considering these view-points, the study was undertaken to compare per capita biomass fuel consumption by rural households of forest and non-forest area in the northern region of Bangladesh. The study also explored the types and sources of biomass fuel, and figured out the collection pattern of biomass fuel in both study areas.

MATERIALS AND METHODS

Two study areas were selected purposively, one for representing the forest area and another for the non-forest area. Birganj upazila (sub-district) of Dinajpur district and Ulipur upazila (sub-district) of Kurigram district were selected as forest area and non-forest area respectively (Figure 1). Birganj National Park and Singra National Park are located in Birganj upazila, while no forest is located in Ulipur upazila. Birganj Upazila is located in between 25°48' and 26°04' N latitudes and in between 88°29' and 88°44' E longitudes (Banglapedia, 2012a). Ulipur Upazila is located in between 25°33' and 25°49' N latitudes and in between 89°29' and 89°51' E longitudes (Banglapedia, 2012b). In Bangladesh a district has some upazilas, an upazila is composed of some unions, a union is composed of some Villages. Birganj upazila covering an area of 413.11 sq km which consists of 11 unions, 187 Villages. The total number of households is 73,895 and average household size is 4.27. The total population of Birganj upazila is 317,253 and the rate of literacy is 48.05 (BBS, 2011). Ulipur upazila covering an area of 458.48 sq km which consists of 13 unions, 354 villages. Total number of households is 103,061 and an average size of the household is 3.83. The total population of Ulipur upazila is 395,707 populations and the rate of literacy is 45.6 (BBS, 2011).

An adaptive multistage random sampling technique was applied to locate the villages and households where upazila was considered as primary sampling unit and households as ultimate sampling unit. The sequence of selection for this study was upazila to union, union to village, village to household. Vognagar union of Birganj upazila and Buraburi union of Ulipur upazilla were selected randomly. Adibashipara, Atharopaika

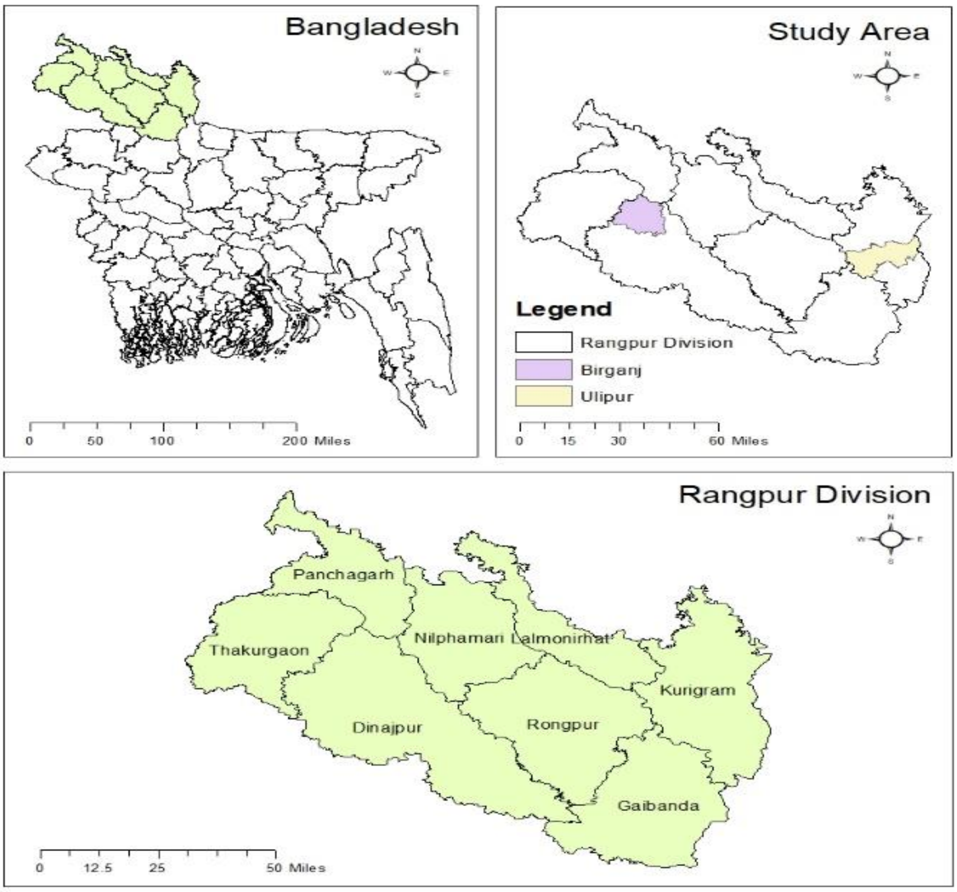

Figure 1. Map of the study areas

were selected randomly among the villages of Vognagar union and Buraburi union, respectively.

The survey was done by a semi-structured questionnaire after completion of a reconnaissance survey. According to preliminary survey the households of both study areas were divided into 3 categories based on the monthly income of the households: poor (less than 10000 BDT), medium (10000-15000 BDT), rich (more than 15000 BDT). A total of 90 households (15 from each category of each area) were selected randomly. The quantity of collection and consumption of biomass fuel was recorded daily basis in local units, later it was converted to kilogram. The survey was conducted from October-December (2019) and data were collected from last ten days of first months, second ten days of second month and first ten days of last month. A paired ranking exercise was also conducted after the interview to find out the fuelwood species were preferred by the respondents. Among the respondents 74% were female, 26% were male in forest area while 66% were female, 34% were male in non-forest area. A total of 63% respondents were illiterate and another 37% were literate in forest area on the other hand 46% of the respondents were illiterate and 54% were literate in non-forest area. The respondents age classes also varied, with 49% were above 50 years, 31% were 30-50 years, 20% were below 30 years in forest area while in non-forest area, 34% of the respondents were above 50 years, 37% were 30-50 years, 29% were below 30 years. Finally, all the data were cross checked in a group meeting at each village involving the people of various level.

The data was analyzed using Microsoft Excel (2013) and SPSS (23.0). ArcGis (10.8) was used for creating the map of the study area. One way analysis of variance (ANOVA) was used for examining significant difference of the variables between forest and non-forest area. ANOVA was also carried out for determining the significant difference of variables between the income groups of each area. Duncan's Multiple Range Test (DMRT) was conducted for identifying significant difference between variables within the forest and non-forest area.

RESULTS

Consumption of Biomass Fuel

Different income groups were found to be consumed various amount of biomass and per capita biomass fuel consumption differed significantly between forest and non-forest area. (Table 1) The average biomass fuel consumption of forest area was found to be 2.10 kg/capita/day. ANOVA indicated biomass fuel consumption of forest area varied significantly ($F=9.69$, $P<0.001$) between the income groups and DMRT revealed only the consumption of poor income group significantly ($p<0.05$) differed from medium and rich income group (Table 1). In non-forest area, average consumption of biomass fuel was 1.71 (kg/capita/day). The consumption between the income groups of non-forest area differed significantly ($F=3.25$, $P<0.05$) and DMRT determined biomass fuel consumption between poor and rich income groups varied significantly ($p<0.05$) while the consumption of medium income group did not differ significantly either with poor or rich income group (Table 1). The maximum amount of biomass fuel was consumed by poor households both in forest (2.28 kg/capita/day) and non-forest (1.81 kg/capita/day) area while less amount of biomass fuel was consumed by rich households both in forest area (1.89 kg/capita/day) and non-forest area (1.57 kg/capita/day) (Table 1).

Types of Biomass Fuel Used

The respondents of the study areas were asked to report on different types of biomass fuel for household use only. The stems, branches, leaves, agricultural residues, cow dung were the different types of biomass fuel used. The overall consumption of these types of biomass fuel varied significantly between forest area and non-forest area except leaves (Table 2). ANOVA determined that consumption of different types of biomass fuel significantly ($P<0.001$) varied between income groups of both forest and non-forest area and DMRT revealed the consumption of all these types of biomass fuel differed significantly ($p<0.05$) among the income groups of both areas (Table 3). Stems of trees were used as a major type of biomass fuel in both forest area (43%) and non-forest area (33%) (Table 3). In the forest area, branches of trees (23%) occupied the second-largest position as a type of biomass fuel used followed by leaves of trees (21%), agricultural residues (7%), cow dung (6%) while in non-forest area, agricultural residues (21%) obtained the second largest position followed by leaves of trees (17%), branches of trees (15%) and cow dung (14%) (Table 3). Rich households of forest area mainly consumed stems (72%), branches (15%), while medium households consumed stems (45%), branches (21%) and poor households consumed leaves (41%), branches (33%) (Table 3). Whereas in non-forest area, rich households mainly met biomass fuel needs as stems

Table 1. Average biomass fuel consumption by the households of the study areas

Income Groups	Biomass Fuel Consumption (kg/capita/day)	Average (kg/capita/day)
	Forest Area	
Poor	2.28 (±0.20) a	
Medium	2.14 (±0.17) b	2.10 (±0.30)***
Rich	1.89 (±0.33) b	
	Non-forest Area	
Poor	1.81 (±0.25) a	
Medium	1.74 (±0.26) ab	1.71 (±0.29)*
Rich	1.57 (±0.31) b	

Note: Same letter(s) in the same column were not significantly ($p<0.05$) different according to DMRT. Asterisks indicated significant (*$p<0.05$, ** $p< 0.01$, *** $p< 0.001$) difference of the variable(s) between the income groups according to ANOVA. Value inside the first bracket indicated standard deviation.

Table 2. Analysis of variance (ANOVA) of the variables between forest and non-forest area

Variables	F Value	P value
Biomass fuel consumption (kg/capita/day)	41.56	<0.001
Sources of biomass fuel		
Forest	112.83	<0.001
Market	0.001	0.973
Agriculture	45.24	<0.001
Homestead	10.53	0.002
Roadside plantation	20.97	<0.001
Types of biomass fuel		
Stems	4.15	0.045
Branches	13.97	<0.001
Leaves	1.72	0.192
Agricultural residues	43.97	<0.001
Cow dung	8.37	0.005

(60%), agricultural residues (23%), medium households as stems (35%), agricultural residues (30%) and poor households as cow dung (34%), leaves (33%) (Table 3).

Sources of Biomass Fuel

Total five sources of biomass fuel were identified in both study areas, as forest, roadside plantation, homestead, market and agriculture. Among the sources, overall contribution of forest, agriculture, homestead and roadside plantation significantly differed between forest and non-forest area except market (Table 2). ANOVA revealed the contribution of all sources varied significantly ($p<0.001$) between the income groups of both areas and DMRT determined the significant ($p<0.05$) difference of the contribution of each sources between the income groups of both forest and non-forest areas (Table 4). In forest area, the maximum amount of biomass fuel was collected from forest (44%) while less amount was collected from agriculture (5%). In non-forest area, maximum amount of biomass fuel was contributed by roadside plantation (31%) followed by market (28%), homestead (24%) and agriculture (17%) (Table 4). Poor households of forest area collected biomass fuel mainly from forest (78%) while poor households of non-forest area mainly collected biomass fuel from roadside plantation (75%) (Table 4). Market contributed the maximum amount of biomass fuel for rich households of both forest area (59%) and non-forest area (48%) while medium households of both areas collected

Table 3. Different types of biomass fuel (%) used by the households of the study areas

Income Groups	Stems	Branches	Leaves	Agricultural residues	Cow dung
Forest Area					
Poor	13 (±7.17) a	33 (±10.39) a	41 (±7.34) a	2 (±2.67) a	11 (±7.65) a
Medium	45 (±11.21) b	21 (±8.91) b	14 (±6.90) b	16 (±6.91) b	4 (±4.70) b
Rich	72 (±21.05) c	15 (±6.40) b	8 (±6.56) c	3 (±3.09) a	2 (±3.03) b
Average	43 (±28.07)***	23 (±11.39)***	21 (±16.02)***	7 (±7.88)***	6 (±6.67)***
Non-forest Area					
Poor	3 (±2.72) a	20 (±5.60) a	33 (±4.51) a	10 (±5.38) a	34 (±17.25) a
Medium	35 (±6.23) b	15 (±5.63) b	12 (±5.38) b	30 (±5.08) b	8 (±6.22) b
Rich	60 (±12.21) c	11 (±4.30) c	6 (±4.79) c	23 (±5.86) b	0 (±0.00) c
Average	33 (±25.24)***	15 (±6.67)***	17 (±12.65)***	21 (±7.85)***	14 (±17.95)***

Note: Same letter(s) in the same column were not significantly ($p<0.05$) different according to DMRT. Asterisks indicated significant (*$p<0.05$, ** $p< 0.01$, *** $p< 0.001$) difference of the variable(s) between the income groups according to ANOVA. Value inside the first bracket indicated standard deviation.

Table 4. Sources (%) of biomass fuel for the households of the study areas

Income Groups	Forest	Market	Agriculture	Homestead	Roadside Plantation
Forest Area					
Poor	78 (±11.20) a	0 (±0.00) a	2 (±1.92) a	8 (±5.01) a	12 (±5.81) a
Medium	39 (±8.85 b	25 (±11.82) b	11 (±7.96) b	17 (±8.72) b	8 (±6.80) b
Rich	15 (±8.51) c	59(±35.14) c	2 (±1.81) a	24 (±9.70) b	0 (±0.00) c
Average	44 (±27.95)***	28 (±32.27)***	5 (±6.38)***	16 (±10.12)***	7 (±7.13)***
Non-forest Area					
Poor	0 (±0.00)	0 (±0.00) a	10 (±6.72) a	15 (±9.21) a	75 (±16.33) a
Medium	0 (±0.00)	37 (±13.94) b	26 (±9.25) b	20 (±8.01) a	17 (±11.64) b
Rich	0 (±0.00)	48 (±33.10) b	16 (±8.72) a	36 (±7.02) b	0 (±0.00) c
Average	0 (±0.00)	28 (±29.01)***	17 (±10.5)***	24 (±10.94)***	31 (±34.42)***

Note: Same letter(s) in the same column were not significantly (p<0.05) different according to DMRT. Asterisks indicated significant (*p<0.05, ** p< 0.01, *** p< 0.001) difference of the variable(s) between the income groups according to ANOVA. Value inside the first bracket indicated standard deviation.

biomass fuel from all sources on average (Table 4).

Collection of Biomass Fuel

Female was identified as predominant collectors of biomass fuel from forest, roadside plantation, homestead and agriculture in both areas. 52% of biomass fuel of forest area and 65% of biomass fuel of non-forest area were collected by the female (Figure 2a). In forest area, male (35%) obtained the second major biomass fuel collector followed by children (13%), while in non-forest area, children (22%) occupied the second position followed by the male (13%) (Figure 2a). Most of the biomass fuel was collected during morning and noon in both areas. In the forest area, 61% of biomass fuel was collected in the noon followed by morning (22%), afternoon (17%) while in non-forest area, 51% of biomass fuel was collected in the morning followed by noon (40%), afternoon (9%) (Figure 2b).

Species Used as Biomass Fuel

A list of 39 species (tree and shrub) was identified as various parts of these were mostly used as biomass fuel in the study areas (Table 5). In forest area, *Shorea robusta* (90%) was most commonly used species followed by *Acacia auriculiformis* (78%), *Eucalyptus camaldulensis* (63%), *Bambusa* sp. (58%), *Melia azedarach* (53%), *Mangifera indica* (45%), *Samanea saman* (40%), *Litchi chinensis* (28%), *Artocarpus heterophyllus* (20%), *Swietenia macrophyll*a (15%) (Figure c). In non-forest area, *Eucalyptus camaldulensis* (80%) was most used species as biomass fuel followed by *Lannea coromandelica* (70%), *Trewia nudiflora* (65%), *Bambusa* sp. (58%), *Acacia auriculiformis* (45%), *Mangifera indica* (45%), *Albizia procera* (35%), *Artocarpus heterophyllus* (30%), *Swietenia macrophylla* (23%), *Neolamarckia cadamba* (13%) (Figure 3).

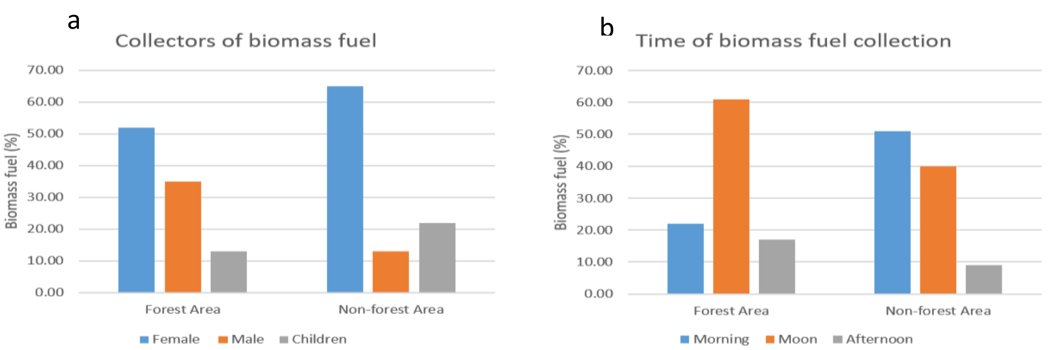

Figure 2. Collectors of biomass fuel (a) and time of biomass fuel collection (b) in the study areas

Table 5. Species used as biomass fuel in the study areas

Forest Area		Non-forest Area	
Local Name	**Scientific Name**	**Local Name**	**Scientific Name**
Akashmoni	*Acacia auriculiformis*	Akashmoni	*Acacia auriculiformis*
Am	*Mangifera indica*	Am	*Mangifera indica*
Amloki	*Phyllanthus emblica*	Bas	*Bambusa* sp.
Bahera	*Terminalia bellirica*	Boroi	*Ziziphus maurutiana*
Bas	*Bambusa* sp.	Chalta	*Dillenia indica*
Chapalish	*Artocarpus chaplasha*	Dogli/Pitali	*Trewia nudiflora*
Dumur	*Ficus hispida*	Eucalyptus	*Eucalyptus camaldulensis*
Eucalyptus	*Eucalyptus camaldulensis*	Henda	*Ricinus communis*
Gamar	*Gmelina arborea*	Jam	*Syzygium cumini*
Ghora-neem	*Melia azedarach*	Jhiga	*Lannea coromandelica*
Guti-jam	*Syzygium jambos*	Kadam	*Neolamarckia cadamba*
Jarul	*Lagerstroemia speciosa*	Kash	*Saccharum spontaneum*
Jolpai	*Elaeocarpus serratus*	Kathal	*Artocarpus heterophyllus*
Kadam	*Neolamarckia cadamba*	Kodbel	*Limonia acidissima*
Kathal	*Artocarpus heterophyllus*	Silkoroi	*Albizia procera*
Lichu	*Litchi chinensis*	Mehogoni	*Swietenia macrophyll*
Mangium	*Acacia mangium*	Neem	*Azadirachta indica*
Mehogoni	*Swietenia macrophyll*	Pakor	*Ficus rumphii*
Minjiri	*Senna siamea*	Peyara	*Psidium guajava*
Raintree	*Samanea saman*	Raintree	*Samanea saman*
Sal	*Shorea robusta*	Segun	*Tectona grandis*
Segun	*Tectona grandis*	Shimul	*Bombax ceiba*
Shimul	*Bombax ceiba*	Sissoo	*Dalberzia sissoo*
Silkoroi	*Albizia procera*	Sonalu	*Cassia fistula*
Sonalu	*Cassia fistula*	Supari	*Areca catechu*
Supari	*Areca catechu*	Tetul	*Tamarindus indica*

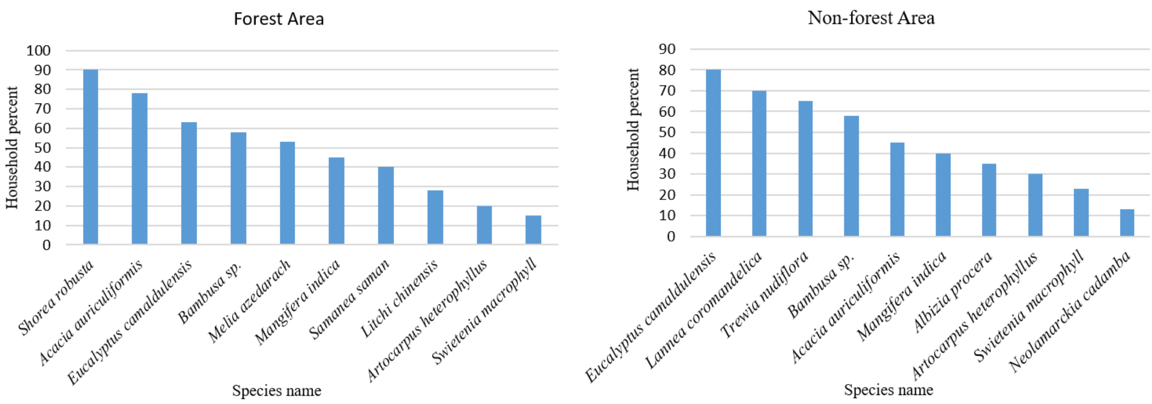

Figure 3. Preference of species for biomass fuel in the study area

DISCUSSION

The present study provided a comparative overview of biomass fuel consumption, collection and preference patterns of forest area and non-forest areas in the rural northern region of Bangladesh. The method of this study was similar to previous studies (Akther *et al.*, 2010; Hassan *et al.*, 2012; Alam *et al.*, 2019). Income is a determinant of social class and it enforces the way of life and biomass fuel consumer behavior, hence household income was the main consideration rather than other demographic profiles for grouping the households into various categories following Miah *et al.* (2003). The moisture content of biomass fuel was not always considered, therefore, the result of this study is an approximation and may not always be accurate. The present study revealed significant difference of per capita biomass fuel and the mean biomass fuel consumption was 2.10 kg/capita/day and 1.71 (kg/capita/day) in forest area and non-forest area, respectively. Bhatt and Sachan (2004) reported maximum and minimum biomass fuel consumption 2.80 kg/capita/day and 1.07 kg/capita/day respectively for households of different mountain villages of India while Kandel *et al.* (2016) reported 1.70 kg/capita/day for the rural households of community forest user groups of Nepal and the finding of the present study is corroborated with these previous studies. Rich households of both areas were found using LPG gas, electricity for cooking and heating while poor households have no such kind of options. Besides few rich households were also found using developed stove but all medium and poor households were found using traditional stoves only. Therefore, rich households of both areas consumed less amount of biomass fuel compared to poor and medium households.

The households of both forest and non-forest area used stems, branches, leaves, agricultural residues, cow dung as biomass fuel that consisted with the findings of Jashimuddin *et al.* (2006), Asaduzzaman *et al.* (2010) and Miah *et al.* (2010). Though the households of both areas used same components of biomass fuel, the present study revealed significant different patterns of biomass fuel consumption among the income groups of both areas. All the respondents opined that mainly household income, availability and accessibility to different types of biomass fuel brought about different consumption pattern. Maximum amount of stems and branches alone (87% in forest area, 71% in non-forest area) consumed by rich households while maximum of amount of leaves, agricultural residues, cow dung alone (54% in forest area, 77% in non-forest area) used by poor households and medium households consumed all types of biomass fuel on average. The finding of the present study is abrogated with Miah *et al.* (2003) that rich households consumed maximum amount of stems and branches alone (94%) while medium households consumed branches and leaves alone (77%) and poor households consumed leaves and agricultural residues alone (54%) in Chittagong region of Bangladesh. The households of forest area depended on the forest for biomass fuel and average 44% of total biomass fuel was contributed by forest while in non-forest-area the contribution of the forest was quenched by agriculture (17%) and roadside plantation (31%). The contribution of market was significantly same on average (28%) for both areas and homestead contributed average 8% more in non-forest area than forest area. All income groups did not have the same access to all sources of biomass fuel. Rich households had the ability to buy biomass fuel and almost all of them had a large homestead, but poor groups were mostly landless and did not have ability to buy. The rich households collected maximum amount of biomass fuel from market (59% in forest area, 48% in non-forest area) and homestead (24% in forest area, 36% in non-forest area). Poor households of forest area collected 78% of biomass fuel from forest while poor households of non-forest area collected 75% of biomass fuel from a roadside plantation. Medium households collected biomass fuel from all sources on average. Miah *et al.* (2003) reported market, homestead, agriculture, plantation contributed average 28%, 33%, 15%, 25% respectively and poor households collected 74% biomass fuel from the plantation, rich households collected 47% biomass fuel from market medium households collected from all sources averagely in rural areas of Chittagong (Bangladesh) which is almost similar to the present study.

Traditionally, women are mainly responsible for the domestic activities in the rural northern region of Bangladesh, therefore, women were found as major biomass fuel collector for both areas though, other family members helped them in biomass fuel collection. Most of the biomass fuel was collected during morning to noon. It is conceded as convenient time for biomass fuel collection by the respondents. Female collected biomass fuel after completing the domestic work in the morning, while male collected when only they got free from professional work. Similar type of gender disproportion in biomass fuel collection by rural households of Bangladesh was also reported by Hassan *et al.* (2013). The present study identified 39 species (tree, shrub) mostly used as biomass fuel in both study areas. *Shorea robusta*, *Eucalyptus camaldulensis* the most commonly used tree species in forest area and non-forest area respectively. The forests of northern Bangladesh is under the classification of tropical moist deciduous forest that mainly composed of *Shorea robusta* (Khan *et al.*, 2007) and *Eucalyptus* sp. were planted extensively in the degraded lands and roadsides of northern Bangladesh for diminishing fuel demand since 1977 (Hossain, 2016). The maximal use is possessed due to the availability of these species in the respective area. Alam *et al.* (2019) identified almost similar species used as biomass fuel in the northern region of Bangladesh and reported *Azadirachta indica* as most preferred followed by *Eucalyptus globules*, *Bambusa* sp., *Artocarpus heterophyllus*, *Mangifera indica*, and *Swietenia mahagoni*.

CONCLUSION

Despite the phenomenal economic condition of the study areas, the poor and medium households have become a pervasive feature of the biomass fuel consumption. The consumption, collection and preference patterns of biomass fuel significantly varied between forest and non-forest area of rural northern Bangladesh. It is aggravating the current situation of a huge amount of biomass fuel collection and creating a continuous pressure on natural forests and agricultural residues, which are very important components of mainly environmental stability and soil fertility respectively. The preferred tree species for biomass fuel sources indicates the high dependency on both natural forests and homesteads and it is alarming for the green future. The consumption of agricultural residues is also alarming in future agricultural food production. Therefore, immediate actions should be undertaken by the respective authorities to increase roadside plantations in forest areas and keep continuing the present plantation activities in non-forest areas for ensuring rural energy security and promoting sustainable energy supply.

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