# Household Biomass Fuel Consumption Pattern in Rural Areas of Bangladesh

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Author RN designed the study in discussion with author MN. Author MN conducted the field work, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors RN and MN managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.*

| *Original Research Article* |

## ABSTRACT

Biomass fuels contribute to the largest share of the energy uses in Bangladesh. The present study determines the household biomass fuel consumption pattern in the rural areas of Titas Upazila under Comilla district in Bangladesh using the stratified random sampling technique through semi-structured questionnaires. Data were collected from 84 households under three household land categories – poor (land area <0.10 acre), middle (land area 0.10-0.25acre) and well-off household (land area >0.25 acre). Households were found to depend largely on biomass fuel including firewood, branches, leaves and twigs, bamboo, agricultural residue (rice husk, rice straw) and cow dung mainly for cooking. Firewood was the dominant biomass fuel for well-off and middle households (28% and 25%) and branches of the tree were dominant fuel for poor households (24%). More than 40% well-off households collect major amount of fuelwood from their own homestead forests while 32% middle and 37% poor households collect tree biomass from agricultural lands. Villagers preferred mostly *Albizia procera, Mangifera indica, Cocos nucifera,*

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*Tamarindus indica* as fuelwood tree species. Households across three categories (poor, middle, well-off) spend 19%, 12% and 11% of their total income for buying biomass fuels, respectively. All of the three households used a traditional wood-burning oven. Among them 39% well-off households and 18% middle households used LPG. Decreasing forest resources impose threats on the availability of biomass fuels. About 70% of households think that fuelwood was a scarce resource because of the degradation of homestead forest and fuelwood production unsustainability. Villagers suggested for alternative fuel items to decrease the pressure on biomass fuel energy sources. They also prescribed inclusion of fast-growing tree species into plantation program at the homestead level. Moreover, they demanded their involvement in this plantation program. The outcome of this study might be helpful to formulate policies to meet future challenges in fuel consumption and their sustainable utilization.

## 1. INTRODUCTION

Energy is one of the fundamental factors in the functioning of any civilized society needed to improve better lifestyle and socio-economic development of the country. Over half of the world's population lives in rural areas, who depend mostly on biomass for their energy supply, and have no access to the modern form of energy [1]. In many developing countries in Asia including India, Pakistan, Myanmar, Nepal and Bangladesh, the rural household energy consumption constitutes over 70% to the national energy use [2]. Households are the foremost end-user of biomass and commercial energy, which varies between rural and urban populations, between low and high-income groups within a country. In Bangladesh, energy resources comprise commercial and biomass resources. Commercial energy resources include natural gas, candle, petroleum products, coal, and hydroelectricity. Biomass resources include wood, bamboo, twigs, wood shavings, sawdust, bark, roots, shell and coir of coconut, agricultural residues such as paddy husk and bran, straw, jute stick, charcoal and cow dung.

The contribution of biomass fuels to total primary energy supply in Bangladesh is about 60% [3,4]. About 77% of the population in Bangladesh live in the rural areas and they need energy for their domestic use such as cooking, crop processing, lighting, agricultural industries, social welfare and commercial activities [5]. The country is one of the most densely populated countries in the world. Population density is about 990 persons per $km^2$ and the population growth rate is 1.54% per annum [6]. Due to the increasing population growth, per capita arable land area decreased from 0.07 ha in 1990 to 0.05 ha in 2009 [6]. Nevertheless, per capita energy consumption increased from 5 GJ (Giga Joules) in 1977 to 6.2 GJ in 2009 [7,8]. The combination of high population growth with decreasing arable land as well as growing energy demand put immense pressure on biomass resources. Moreover, because of overexploitation of natural and homestead forests, fuel shortage intensity is being increased day by day [9,10]. Therefore, the country is expected to remain heavily dependent on biomass resources for energy supply in the near future.

Several studies have been conducted on various aspects of the use of biomass fuels in Bangladesh. A study [11] was conducted on biomass fuel used by the rural households in Chittagong region, Bangladesh. A further study [12] investigated the preference and consumption pattern of biomass fuel in some disregarded villages of Bangladesh. But no research was conducted to investigate the household biomass consumption pattern in the rural households of Comilla district in Bangladesh. So this study was conducted to understand the biomass fuel availability, it's consumption pattern by various wealth categories households living in Titas Upazila under Comilla district. The findings of the study are expected to contribute to sustainable energy development in Bangladesh.

## 2. MATERIALS AND METHODS

### 2.1 Study Sites

The study was conducted at Titas Upazila in Comilla district (Fig. 1). The Upazila has an area of 109.30 sq. km or 42.20 sq. mile. It is located between 23º25' and 23º39' north latitudes and between 90º31' and 90º53' east longitudes. The Upazila is bounded on the north by Homna Upazila, on the east by Muradnagar Upazila, on the south by Daudkandi Upazila and on the west by another newly derived Meghna Upazila. Main rivers of the Upazila are Gumti and Titas.
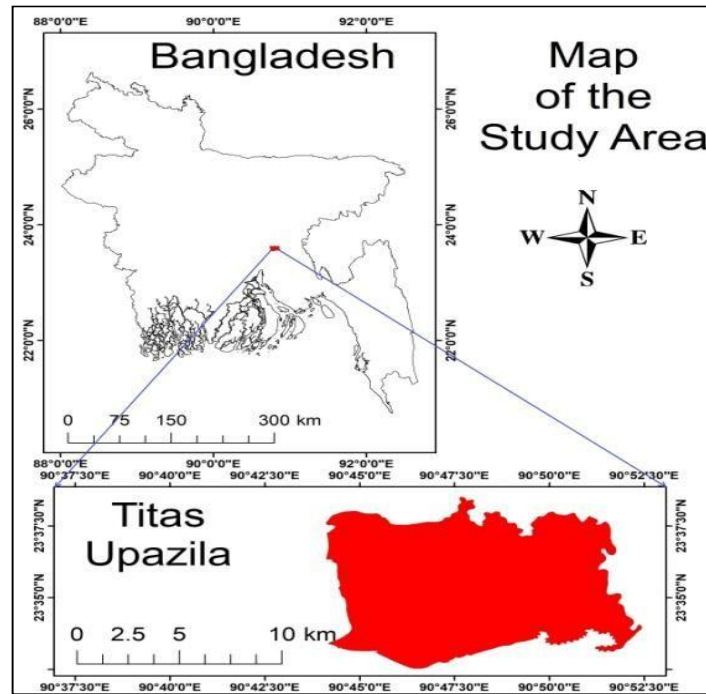
**Fig. 1. Map of Titas Upazila showing the study areas**

Stratified random sampling was used to select the study areas and households. The sequence of selection was from upazila (sub-district) to union, union to village and then village to households. Out of nine upazilas in Comilla district, only two unions named Jagatpur and Balarampur were selected under this study. Then two villages were selected randomly in each upazila, giving a total of four villages. The four villages are namely Jagatpur, Bhatipara, Biramkandi and Shreenarayankandi. The households were categorized into three predetermined wealth categories (well-off, middle and poor) based on their land sizes (Table 1). Moreover, twenty one households (7 households from each wealth category) from each village (total 84 households) were selected randomly.

**Table 1. Household category based on land**

| Household category | Poor | Middle | Well-off |
|---|---|---|---|
| Land size (Acre) | <0.10 | 0.10-0.25 | >0.25 |

## 2.2 Data Collection

Researchers conducted four discussion meetings with the selected village people specially old, village leader, women, a representative from local administrative office to get the overall picture regarding the household occupation, income, wealth categories etc. of the two unions. Information on wealth status i.e. land sizes of household were collected from the local administrative offices as they have the base data for each household. Based on their information, researchers finally categorized the households into three wealth categories i.e. well-off, middle and poor. Finally, seven households from each category household (84 in total) were selected purposively for survey. Field work was carried out in several weeks during January – May, 2019.

Household survey was carried out using a semi-structured questionnaire. Family heads responded most of the questions, but other family members especially women also answered questions. Data were collected on demography, literacy, house condition, occupation, meal landholding area (ha), mean monthly income (taka, finally converted into US$). Respondents were asked about their income from different sources i.e. agriculture, business, service, daily labour. They were also asked about the expenditure on biomass fuel consumption purposes. Moreover, the respondents were also questioned about biomass fuel sources, collection of biomass fuels, choice of species, types of cooking stoves

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uses. The data were validated by rechecking and revisiting with the respondents. Sometimes, mobile phones were also used to talk with the villagers to validate the data. Finally, data were analyzed using the MS Excel.

## 3. RESULTS AND DISCUSSION

### 3.1 Socio-economic Profile of the Households

Socio-economic profile of the sampled households is summarized in Table 2. The majority of the respondents (51-67%) in middle and poor categories were engaged in agriculture whereas 29% of the respondents from well-off households were involved in agriculture. Moreover, 36% respondents from well-off households, followed by middle (23%) and poor (19%) were engaged in business. Less involvement in service, teaching and as doctor was observed as profession among the three categories of households. Apart from these, the mean annual monthly income across the three categories of households was found as US$ 258, 160 and 80, respectively. The reason for this income variation was that the lion's share of income of well-off households generated from business and agriculture. Moreover, mean landholding area (ha) was accounted as 0.28 ha for respondents from well-off households followed by middle (0.08 ha) and poor (0.16 ha). The majority of the poor households (78) had kacha (mud-walled with tin/sun-grass/bamboo-mat roofs) houses whereas half of the well-off households (50) had semi-pacca (brick-walled with tin roofs) and middle households had kacha (33) and pacca (39) houses at the study area.

### 3.2 Types, Sources and Quantity of Biomass Consumption

Different sources of biomass fuel were identified at the study area. Irrespective of the household categories, the major sources were market, homegarden, animal, agricultural land, neighbor and roadside. In accordance with priority ascending, those were own homestead and agricultural land, market, neighbor and road-side. From the study it was found that agricultural land was the major source of biomass fuel for poor households (37%) (Fig. 2). Two research studies [12,13] found almost similar results in other parts of Bangladesh. Most of the poor household respondents' occupation was farming and they did not have much home garden. So, agricultural land was the major source of biomass fuel for them. In the case of middle households,

agricultural land (32%) and local market (29%) was their major sources of biomass collection. But for well-off households, homegarden (41%) and local market (37%) were the major sources of biomass fuel wood collection (Fig. 2). The reason behind this is, well-off households had maximum amount of land (16.39) covered with home garden followed by poor (12.84) and middle (13.26) (Table 3). It is also clear from the table that maximum land was used as a pond for all categories of households except poor households giving priority for house construction (46.84). Well-off household respondents collect their necessary fuel from the home garden. It is evident from the study that the rural household with limited sources of homegarden and agricultural land, but had the purchasing capacity, bought firewood or branches from the local market. Local markets meet the demand of large amount of fuel wood scarcity. But the households usually with less purchasing capacity were reported to collect biomass fuels from their neighbors and also from road-side. Cowdung from animals was another source of fuel for many rural households. The overuse of fuelwood is significantly sharing the deforestation process. In addition to this, there was increased use of crop residues and cow dung as fuel which was depriving the agricultural soil of valuable nutrients and organic matter resulting to reduce the productive capacity of land [14].

Regardless of the household categories, the most used biomass was firewood (Table 4), followed by other categories. On average, well-off households consumed 0.093 ton (43% of total biomass) of firewood in a month followed by tree branches (0.034 ton, 22%), cow dung (0.0102 ton, 15%), and leaves and twigs (0.016 ton, 10%), rice husk and straw (0.014 ton), bamboo (0.0012 ton) (Table 4). Households of middle category were found to use the highest amount of firewood (0.060 ton per month, 37% of total biomass) followed by other types. Moreover, poor households used tree branches (0.039%), firewood (0.033%) as major biomass types among others.

### 3.3 Purposes of Biomass Consumption

Households in the study areas used biomass fuels for different purposes including cooking, water boiling, paddy parboiling, and making livestock feeds (Table 5), 65% of total biomass across the three household categories were used for cooking meals in addition to occasional tea and rice-cake making. Well-off and middle category households used a higher amount (12-

28% of biomass) for preparing food for their livestock than the poor did. A research study [15] drawing data from four agro-ecological zones of Bangladesh reported that on an average 88% of total biomass fuels was used for cooking purposes. It is reported [16] that the households of the northern regions used considerably higher percentage (23%) of biomass fuels for rice parboiling, little higher than the value (19%) found under this study. The reason may be that farmers in that region parboil rice for commercial purposes and they also consume boiled rice.

## 3.4 Type of Oven Used

The entire households of the study area used the mainly traditional wood-burning oven for cooking and other purposes. The users of traditional wood-burning stove increased from well-off to the poor households, while in the case of LPG gas stove, the trend was opposite (Fig. 3). This was due to the availability and cheapness of biomass fuels, compared to the other commercial fuels, such as LPG. Thus, the poor with economic inability had to use traditional wood burning stove, and well-off with the better financial condition was relatively moving to the use of the gas stove.

## 3.5 Fuel Consumption and Expenditure

Mean monthly expenditure for total fuels was US$ 28.01, 19.67 and 15.74, respectively for well-off, middle and poor households, respectively (Table 6). It can be inferred that well-off households having more income, spend more on high-quality fuels (e.g. firewood). The well-off households spent nearly double for fuels than that of the poor. Similar results were reported by Hassan, et al. 2013.

## 3.6 Income and Biomass Expenditure

The study showed that average income of the household was about 12988.61 Tk/month with maximum income (20307.69±1606.83) Tk/month/ household for well-off households and minimum income for poor households (6222.22± 913.02) Tk/month/household. Biomass expenditure was the maximum amount for well-off households (2182.29±228.78 Tk/month/household) and minimum for poor households (1227.78±123.67) Tk/month/ household). Households across three categories (poor, middle, well-off) spend 19%, 12% and 11% of their total income for buying biomass fuels, respectively (Table 7).

The analysis depicts that well-off households occupy the maximum income because most of the people in this category were involved in business and job. It is also illustrated from the table that poor households hold the minimum income as most of them were a farmer. Moreover, average biomass consumption and expenditures were maximum for well-off households because their economic status was quite good (Table 7).

## 3.7 Preferred Fuel Wood Species Used by Rural Households

The rural households used either whole tree or looped branches as firewood. Different types of fuelwood species were used by the household for everyday cooking. Rural households usually collect their biomass fuel mainly from homestead and agricultural land. Therefore tree species were planted in homestead areas. Respondents reported a total of 15 species including timber, fruits and multipurpose tree species used as firewood in their households. Based on the respondent's overall preferences, Sil Koroi (*Albizia procera*), Am (*Mangifera indica*), Tentul (*Tamarindus indica*), Narikel (*Cocos nucifera*) were used mostly among other tree species. Jam (*Syzygium grandae*), Mahagoni (*Swientenia mahagoni*), Gab (*Diospyros peregrine*), Tal (*Borasus flabilifer*), Shewra (*Streblus asper*), Kafila (*Guruja pinnata*), Boroi (*Ziziphus mauritiana*), Hizol (*Barringtonia acutangula*), Pati bet (*Schumannianthus dichotomus*), Menda (*Litsea glutinosa*), Kanthal (*Artocarpus heterophyllus*) were other tree species that used by the households as fuel wood species.

Sil koroi (*Albizia procera*) was preferred mostly because of higher production of fuel wood and leaves and twigs. *Albizia procera* also grows naturally and abundant in the study area. Moreover, Am (*Mangifera indica*), Tetul and Narikel trees were also chosen more among others. These are fruit tree species and grown in most of the houses as a source of nutrition and economic value. These tree species also produce large amount of leaves, twigs and branches which is used for households cooking purposes. Nath, et al. [17] also identified 16 species growing in homestead of Sal forest area where most preferred tree species were *Albizia procera*, *Acacia auriculiformis*, *Artocarpus heterophyllus* and *Swientenia mahagoni*. Hasan, et al. [15] also stated that Rain tree, Sil koroi tree, Am where the most preferred fuel wood species at the rural household level.
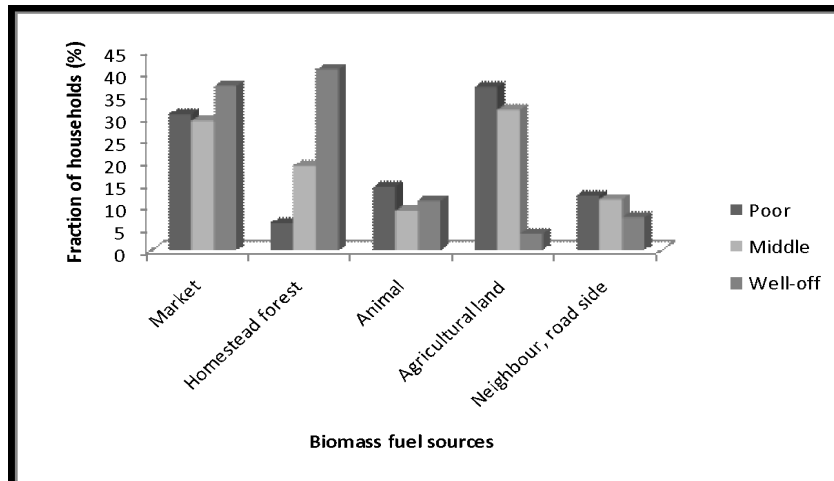
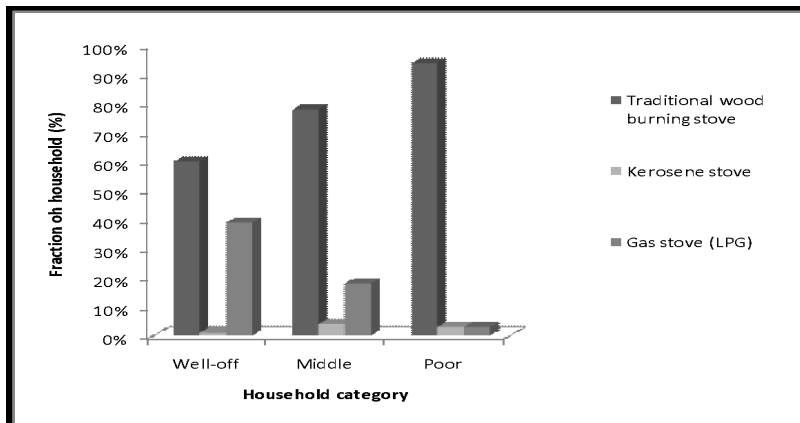**Fig. 2. Sources of traditional biomass fuels in the study areas**



**Fig. 3. Types of biomass cooking stove used by the households in the study areas**

**Table 2. Basic socio-economic profile of the sample households**

| Variable | Household category | | |
|---|---|---|---|
| | **Well-off** | **Middle** | **Poor** |
| Literacy rate (%) | 100 | 95 | 62 |
| Primary | 7 | 39 | 48 |
| Secondary | 36 | 41 | 7 |
| College | 29 | 13 | 7 |
| Graduation | 28 | 2 | - |
| **Occupation (%)** | | | |
| Business | 36 | 23 | 19 |
| Agriculture | 29 | 51 | 67 |
| Service | 14 | 16 | 11 |
| Teaching | 21 | 8 | 3 |
| Village doctor | - | 2 | - |
| **House condition (%)** | | | |
| Kacha | 21 | 33 | 78 |
| Semi-pacca | 50 | 28 | 11 |
| Pacca | 29 | 39 | 11 |
| **Mean landholding area (ha)** | 0.28 | 0.08 | 0.16 |
| **Mean monthly income (US$)** | 258 | 160 | 80 |

**Table 3. Distribution of households land in the study area**

| Household Category | Total land covered (%) | | | | | |
|---|---|---|---|---|---|---|
| | House | Yard | | Cattle shed | Pond | Home garden |
| | | Front | Back | | | |
| Poor | 46.84 | 17.44 | 3.39 | 2.72 | 16.77 | 12.84 |
| Middle | 28.09 | 17.05 | 8.03 | 2.22 | 31.35 | 13.26 |
| Well-off | 17.15 | 15.23 | 4.62 | 1.58 | 45.03 | 16.39 |

**Table 4. Biomass fuel consumption by households in the study areas**

| Biomass type | Consumption (Ton/month) | | | Mean for study area (Ton/month) |
|---|---|---|---|---|
| | Well-off | Middle | Poor | |
| Firewood | 0.093 | 0.060 | 0.038 | 0.063 |
| Tree Branches | 0.034 | 0.033 | 0.039 | 0.035 |
| Cow dung | 0.0102 | 0.012 | 0.008 | 0.01 |
| Leaves & twigs | 0.016 | 0.013 | 0.02 | 0.016 |
| Rice husk, straw | 0.014 | 0.017 | 0.022 | 0.018 |
| Bamboo | 0.0012 | 0.00075 | 0.0031 | 0.0017 |
| Total | 0.17 | 0.14 | 0.131 | 0.143 |

**Table 5. Purpose of biomass fuels used by households in the study areas**

| Household Category | Use of biomass fuel (%) | | | |
|---|---|---|---|---|
| | Well-off | Middle | Poor | Mean |
| Cooking | 62 | 67 | 68 | 65 |
| Boiling | - | 2 | - | 1 |
| Paddy Parboiling | 10 | 19 | 28 | 19 |
| Livestock | 28 | 12 | 4 | 15 |

**Table 6.Total cost (US$) of different fuel types used by different household categories**

| Fuel type | Household category | | |
|---|---|---|---|
| | Well-off | Middle | Poor |
| Biomass (Ton) | 0.17 (13.26) | 0.14(10.92) | 0.13(10.14) |
| Kerosene (Liter) | 0.03 | 0.089 | 0.35 |
| LPG (Tk) | 29.62 | 225 | 571.42 |
| Total cost (US$) | 28.01 | 19.67 | 15.74 |

*Note: Figures in parenthesis indicate cost (US$)*

**Table 7. Household income and expenditure of the study area**

| Household category | Income (Tk/month/household) | Biomass expenditure (Tk/month/household) | (%) of expenditure to the total income |
|---|---|---|---|
| Poor | 6222.22 (913.02) | 1227.78 (123.67) | 19 |
| Middle | 12435.90 (862.85) | 1534.01 (84.39) | 12 |
| Well-off | 20307.69 (1606.83) | 2182.29 (228.78) | 11 |

*Note: Figure in the parenthesis indicates standard error of mean*

## 3.8 Fuel Wood Scarcity and Reasons Behind

The study showed that poor households had acute fuel wood scarcity (100%). In case of middle households the fuel wood scarcity percentage was 71.79%. On the other hand, well-off households had less fuel wood scarcity.

14.28% respondents told that they faced the problem of fuel wood scarcity and the rest of 85.72% respondents told that they did not have fuel wood scarcity because they had their own homestead forest.

Maximum households think that fuel wood is a scarce resource because they had to spend

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much amount of money to buy fuel wood. Above 85% respondents said that they normally face shortage of biomass fuels particularly in rainy season. This result is consistent with the research finding of Nath, et al. [17]. Major respondents (37%) of the study area said that fuel production unsustainability was the main reason for fuel wood scarcity. Fragmentations of homesteads put negative role on sustainable supply of fuels. Another main reason was the reduction of the number of tree species due to construction of houses for increasing number of family members in the study areas.

## 3.9 Villager's Suggestions

During the survey, few suggestions were found from the household level regarding fuel wood scarcity at the study areas which are mentioned below:

- In areas where unsustainable harvesting is leading to forest loss and degradation, home gardens can act as an initial alternative to biomass harvesting from forests.
- Plantation program in the village areas also can minimize the shortage of fuelwood problem.
- Necessary steps should be adopted so that poor households' people can involve themselves in a plantation program and can be economically benefited.
- It is recommended that fast-growing species (any species from their selection) with high calorific values and substantial growth and branching capacity should be planted to address the fuelwood problem.
- Improved management practices for homestead forest need to be developed to increase the productivity of homestead.
- Alternative fuel items can decrease the pressure on biomass fuel energy sources. Improved cooking stoves should be introduced throughout the rural areas with minimum cost so that they are easily accessible to the local people who are dependent on the homestead forest for their daily energy needs.
- The Government and NGO efforts should be strengthened to disseminate this technology.

## 4. CONCLUSION

Population pressure is causing homestead land fragmentation in rural areas which represents

that homestead forest will lose it's diversity and density day by day. In addition, use of agricultural residues and cow dung as biomass fuel would put negative impact on land fertility and hence on agricultural productivity. Bamboo is also used as biomass fuel which indicates the negative pressure on other uses of bamboo at the household level. These scenarios may bring our poor class society to face serious poverty problem. All these problems should be solved keeping in view the villager's suggestions along with some other recommendations. Villagers should be motivated to plant fuel wood species at their homestead level as well as another vacant land. Moreover, villagers should be motivated to use improved cooking stoves. However, relevant authorities (e.g. NGOs, concerned government agencies) need to ensure that such stoves are readily available at a reasonable price. Authorities may supply subsidized stoves and provide training to local people on the construction of stoves. Improved stoves would reduce dependency on traditional biomass and reduce health risks.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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