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TRADITIONAL BIOMASS FUEL CONSUMPTION BY RURAL HOUSEHOLDS IN DEGRADED SAL (*SHOREA ROBUSTA*) FOREST AREAS OF BANGLADESH

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ABSTRACT

This study explored the availability and consumption pattern of various traditional biomass fuels, preference of and expenditure for biomass fuels, problems with the uses of biomass fuels and villagers' strategy to cope with the biomass fuel problems. Data were collected from 330 households under three wealth categories – well-off, middle and poor households. Households were found to depend largely on biomass fuel including firewood, branches, leaves and twigs, bamboo, straw, husk and cow dung mainly for cooking. Firewood was the dominant biomass fuel of well-off households (43%) whereas middle (37%) and poor households (35%) used tree branches. Total biomass, firewood and cow dung consumption by well-off households was significantly higher than that of middle and poor households. More than 60% well-off households and 44% households of middle category collect tree biomass from their own homestead forests while 59% of poor households gather from neighbour's homestead forests. Villagers preferred *Albizia saman, Acacia auriculiformis, Artocarpus heterophyllus, Swietenia mahagoni and Albizia procera* as fuel wood tree species. Households across three categories spend 8%, 13% and 16% of their total income for buying biomass fuels, respectively. Decreasing forest resources impose threats on availability of biomass fuels. Although 27% well-off households were using improved cooking stoves (ICS), mass motivation and subsidized ICS can increase their uses. Along with reforestation programs government may take initiative for trading carbon offsets from ICS programs on carbon markets as part of the Clean Development Mechanism (CDM).

Keywords: Biomass, firewood, cooking stove, reforestation, CDM

1. INTRODUCTION

Biomass generally includes both plant and animal biomass. Biomass-based fuels are mainly derived from three sources: agricultural residues, forestry residues and energy crops [1]. Woody biomass accounts 87% of the total annual biomass use globally [2]. It is the most common source of energy domestic, commercial and industrial sectors in almost all developing countries [3]. Nearly half of world population living in poor countries depends on traditional biomass resources to meet their basic fuel needs [1]. Biomass-resources have an important role in meeting the growing needs of energy of the globe, especially those of the developing countries where biomass fuels accounts for approximately 38% of total energy consumption [4].

Traditional biomass fuel refers to the direct combustion (often in highly inefficient devices) of wood, charcoal, leaves, agricultural residue, animal and human waste and urban waste, for cooking, drying and charcoal production [5]. It 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 countries [5]. Traditional forms of biomass can be readily converted into all energy carriers (heat, electricity, liquid and gas), offering employment options to reduce poverty and if burnt efficiently these could release low carbon [6].

The low cost traditional biomass fuel does not require processing before use [7].

According to the Bangladesh Bureau of Statistics biomass fuels are the principal sources of energy supply in rural areas contributing more than 90% to the primary total energy supply [8]. These traditional biomass fuels consist of agricultural residues including paddy husk and bran, straw, bagasse, jute sticks, and forest residues including firewood (i.e. stem and main branches), twigs, leaves, bark, roots, woody debris and animal wastes. Rural households use biomass fuels mainly for domestic cooking, rice parboiling, cloth washing, molasses making, and to some extent for cooking food for livestock [9]. However, the consumption pattern of traditional biomass fuel is influenced by many factors including socio-economic and demographic status, literacy of household head, and availability, cost and distance to the sources of resources [10, 11, 12]. Thus, assessment of fuel consumption as well as the interaction and balance between various sources and end-user sector at the household level are prerequisites for formulation of bio-energy policies at regional and national level [9]. Reliable databases on traditional biomass fuel use are highly important to formulate appropriate policy and field-oriented interventions [5].

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2. OBJECTIVE (S) OF THE STUDY

There have been a number of studies on biomass fuel consumption and uses in Bangladesh. For example, Miah et al. [13, 14] and Akhter et al. [15] found that biomass fuel uses and consumption by rural households in the southern and central regions of Bangladesh. Jashimuddin et al. [16] examined the preference and consumption pattern of biomass fuels in the coastal region. Hassan et al. [9] analyzed biomass energy consumption pattern in four agro-ecological regions of Bangladesh. Hassan et al. [9] argued that there is little information available on current rural household energy consumption pattern in terms of types of fuel, quantity and sources of fuels, and energy expenditure.

It is apparent that there is a scarcity of information on the biomass fuel consumption pattern by rural households in forested areas of Bangladesh. Moreover, no information is available on the biomass fuel consumption pattern by villagers of various wealth categories. Therefore, this exploratory study was conducted in degraded Sal (*Shorea robusta*) forest areas of Bangladesh, and explored:

- the availability and consumption pattern of various traditional biomass fuels by three wealth categories of people namely well-off, middle and poor;
- preference of and expenditure for biomass fuels; and
- problems with the uses of biomass fuels and villagers' strategy to cope with the problems.

The study was designed to provide biomass fuel related information to policy makers that might help them in planning rural energy development in Bangladesh.

3. MATERIAL AND METHODS

3.1 Study sites

This study was conducted in Sal forest areas. Once the areas consisted of dense natural Sal forests, but due to indiscriminate illegal logging only small patches of degraded forests now remain in Dhaka, Gazipur, Mymensingh and Tangail districts. Stratified random sampling was used to select study sites and households. Stratification was on a spatial basis then on wealth ranking. Selection of study sites followed district to upazila (sub-district), from upazila to union council, from union council to village and then households from selected villages. One upazila (Sreepur) from Gazipur and two upazila (Fulbaria and Nandail) from Mymensingh district, respectively.

Next, the names of all villages in each selected upazila were gathered from respective upazila and union council offices, and then two villages were selected in each upazila, giving a total of six villages. Selection at every stage was done randomly using random number table.

3.2 Data collection

For data collection, researchers first walked through the selected villages and held a meeting in each village with elderly and respected persons (4-6 persons attended) including the village leader. Three issues – informing the purpose of research, gathering information on number of households and the overall biomass fuel situation in the respective village – were discussed at the meetings. A checklist was prepared and used to facilitate the discussions. Information was written down during discussions and reconfirmed by reading it back to the participants.

Village walks explored wealth disparity among villagers and thence carried out a participatory wealth ranking exercise in each village (following Grandin [17]) with the help of four key-informants including the village leader. These informants were chosen from four parts of a village representing three wealth classes and it was assumed that they would provide reliable information because they knew all villagers. A list of all households was prepared, with a separate card number with the name of household head for each household. All cards were then ranked by the key informants independently, based on criteria each chose following their discussion. Finally, three wealth groups – labeled well-off, middle and poor – were identified (Table 1). Around 50% households (30 households from well-off, 84 from middle and 216 poor households) were selected proportionately and randomly (using a random number table) for household survey, a total of 330 households being included in the sample. Field work was carried out in several weeks during August – December 2010.

Table 1: Grouping of households into three categories based on participatory wealth ranking methods

Wealth category	Wealth indicators	No. of households
Well-off	Have agricultural land Have food sufficiency and surplus Have livestock, mostly cows Have non-farm income from services and business With more educated household members Have *pacca* (brick-walled) houses	65
Middle	Limited and leased agricultural land Have livestock, but all of them do not have cow Have off-farm income from services and business May labour on other's farms Have semi-*pacca* and *kacha* (mud-walled) houses	167
Poor	Almost no agricultural land except homestead land Mostly leased farmers Work as daily labourer Have livestock, but few cows, if any Mostly *kacha* house	440

A Household survey was carried out using a semi-structured questionnaire. Family heads answered most of the questions, but other family members (mainly spouses) present during interviews also sometimes answered some of the questions.

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 537-544*

When there were conflicting answers, we waited for a consensus to emerge. Data were collected on demography, literacy, house condition, occupation and livestock status. We asked respondents about monthly earnings from various sources to estimate household mean monthly income. Respondents reported an average monthly income after considering various sources (e.g. agriculture, business, service and daily labour). We also asked them how much they spend for fuel purposes. Data were obtained about biomass fuel sources, prices of fuels purchased from markets, monthly consumption of various different biomass fuels, collection of biomass fuels, choice of firewood species, types of cooking stove uses and opinions on use of an improved stove. Household total biomass fuel consumption was calculated by totaling different fuel sources. Some households were subsequently revisited for clarification.

Quantitative data were summarized into averages and percentages, and one-way analysis of variance (ANOVA) was conducted to explore statistically significant differences between means of some variables. Pearson correlation tests were performed to test whether relationship (positive or negative) exists between household fuel consumption and other variables.

4. RESULTS AND DISCUSSION

4.1 Socio-economic profile of the households

Socio-economic features of the sampled households are summarized in Table 2. The majority of the respondents (48% and 55%) in well-off and middle wealth categories were engaged in agriculture whereas 53% of respondents in poor categories were daily labourers. More than 80% of well-off households had cows (mean number 3.5), goats (5.5) and poultry (9.0). Nearly 60% of households in the middle wealth category had livestock and only a few households of poor families had livestock. Considering all sources, the mean monthly income across three categories of households was found as US$ 259, 122 and 68 respectively, which was significantly different (ANOVA: df=2, F=16.75, P<0.01). The reason for this difference was that the lion's share of income (85%) of well-off households comes from service and business. The majority of houses in the well-off and middle categories (57% and 67%) well-off were semi-*pacca* (brick-walled with tin roofs) and 97% of poor households had *kacha* (mud-walled with tin/sun-grass/bamboo-mat roofs) houses. All households in three wealth categories had access to electricity but there was no natural gas supply in the study areas.

4.2 Types, sources and quantity of biomass consumption

The rural households are largely depended on biomass fuel including firewood, tree branches, leaves and twigs, bamboo, straw, husk and cow dung (Table 3). All the three categories of households were found to use firewood, tree branches, cow dung, and leaves and twigs as biomass fuel.

Six sources of biomass were identified from where household members across the three wealth categories collect biomass fuels (Fig. 2). It was found that 62% of the well-off households and 44% of the middle-wealth households collect biomass mainly of firewood, tree branches, and leaves and twigs from their own homestead forests. Homestead forest is a multi-storied forest consisting of trees, shrubs, herbs and palms, traditionally grown around the homestead. On the other hand 59% of poor households gather biomass mainly of dry small tree branches, leaves and twigs from neighbouring homestead forests (a common customary practice in rural Bangladesh). Another 48% of poor households reported that they collect small branches and dry leaves from the nearby Sal forest, a public forest in central region of Bangladesh. It was also found that 20% of households of the middle wealth category collect fallen dry leaves and dry wood from the Sal forest.

Table 2: Basic socio-economic profile of the sample households

Variable	Household category		
	Well-off	**Middle**	**Poor**
Household size (mean no.)	5	5	4.7
Literacy rate (%)	100	86	62
Primary	20	40	31
Secondary	35	21	21
College	31	17	8
Graduation	14	8	2
Occupation (%)			
Business	23	11	8
Agriculture	48	55	32
Service	29	23	7
Day labour	-	11	53
Livestock (mean no.)			
Cow	3.5(100)	3.5(62)	1(16)
Goat	5.5(87)	3.5(50)	2.5(32)
Poultry	9(84)	5(66)	2.4(53)
House condition (%)			
Kacha	7	30	97
Semi-kacha	57	67	3
Pacca	36	3	-
Mean landholding area (ha)	1.4	1.1	0.2
Mean monthly income (US$)	259	122	68

During the household survey members (mainly women and children) of poor households were observed to collect fallen leaves and small dry branches from nearby Sal forest as well as from neighbouring homestead forests. Collection takes place in the dry seasons (November through April) with storage for use in rainy season (June-September). They also gather agricultural residues, the basal portion of the paddy grass which is left in the field after harvesting, during winter.

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 537-544*

Well-off households use rice husk, straw and bagasse which they collect from their agricultural fields. During fieldwork, household members were observed to make cow dung stick and cake which they store for use in rainy season. Only a few households – 20% of those in well-off category – reported to purchase firewood from markets.

Researcher identified 16 tree species growing in homestead forests and used by households across three wealth categories for firewood. Among 16 tree species households, the most preferred were *Albizia saman, Acacia auriculiformis, Artocarpus heterophyllus, Swietenia mahagoni and Albizia procera.* They opined that these species grow faster on their homesteads and marginal land, burn uniformly and require relatively low time to cook food.

Hassan et al. [9] reported that homestead forests are the main source of firewood supply in rural Bangladesh and people traditionally collect firewood from neighboring public forests. Islam and Sato [18] reported that 72% of poor households collect firewood from Sal forest areas in Bangladesh, and asserted that firewood is collected mostly in uncontrolled and illegal ways, and as a consequence, forests and species in the Sal forests are experiencing reduction day by day.

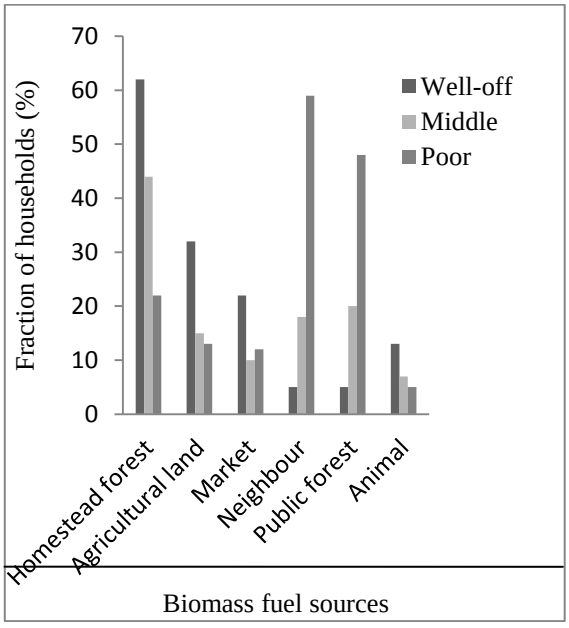

Fig. 2. Sources of traditional biomass fuels in the study areas

On average, well-off households consumed 0.18 ton (43% of total biomass) of firewood in a month followed by tree branches (0.09 ton, 22%), cow dung (0.06 ton, 15%), and leaves and twigs (0.04 ton, 10%) (Table 3). Households of middle category were found to use the highest amount of tree branches (0.13 ton per month, 37% of total biomass) followed by firewood (0.12 ton, 35%), cow dung (0.04 ton, 12%), and leaves and twigs (0.03 ton, 8%).

The poor households mostly used tree branches (0.10 ton per month, 35% of total biomass) followed by firewood (0.08 ton, 31%), leaves and twigs (0.06 ton, 20%) and cow dung (0.03 ton, 9%) (Table 3). ANOVA testing reveals that quantity of firewood consumption by well-off households was significantly higher (df=2, F=3.65, $P<0.05$) than that of middle and poor wealth category households. Cow dung consumption was also significantly different across three categories of households (df=2, F=3.48, $P<0.05$). Total biomass consumption among three categories of households was also significantly (df=2, F=22.72, $P<0.01$) different.

Some researchers [e.g. 9, 15, 19] have reported that firewood is the main source of biomass fuel in rural Bangladesh. Guta [1] mentioned that woody biomass constitutes 95% of total biomass supply in Ethiopia. Respondents of well-off households said that they prefer firewood because it cooks food quickly, is available at their homestead forests and generates relatively little smoke. Rural households who are well-off and have higher educational background prefer using firewood to other biomass fuels [9].

Table 3: 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	0.18	0.12	0.08	0.13
Tree branches	0.09	0.13	0.10	0.10
Cow dung	0.06	0.04	0.03	0.04
Leaves and twigs	0.04	0.03	0.06	0.04
Bamboo	0.01	0.009	0.006	0.009
Straw	0.01	0.008	0.005	0.008
Bagasse	0.008	0.003	0.002	0.005
Husk	0.006	0.005	0.002	0.004
Total	0.42	0.34	0.18	0.35

Cow dung is also an important biomass source for rural people. Akther et al. [15] observed that on an average household used 0.04 ton of cow dung per month which is similar to the findings of this study. Sarker and Islam [20] noted that cow dung contributes about 3% of total biomass fuel consumption in Bangladesh. All respondents commented that when there was plenty of woody biomass resource in their localities they used cow dung as manure in their rice fields. Now-a-days due to fuel wood crisis and higher prices of purchased firewood, they use cow dung for cooking purposes. The diversion of cow dung from use as an organic fertilizer has a negative impact on soil fertility. Use of the cow dung as fuel for cooking is certainly decreasing the fertility of the agricultural land resulting to low productivity of the agricultural crops [21].

4.3 Purposes of biomass fuel consumption

Households in the study areas used biomass fuels for different purposes including cooking, water boiling, paddy parboiling, and making livestock feeds (Table 4).

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 537-544*

Nevertheless, 75% of total biomass fuels across three household categories were used for household cooking purposes. They used biomass fuels for cooking meals in addition to occasional tea and rice-cake making. Nearly 9% of the biomass was used for water boiling, usually in winter for taking baths by the elderly members. Well-off and middle category households used 10-11% of biomass for preparing food for their livestock. Hassan et al. [9] drawing data from four agro-ecological zones of Bangladesh reported that on an average 88% of total biomass fuels was used for cooking purposes. Asaduzzaman et al. [22] found that nearly 90% of biomass fuel was used for cooking. Sarkar and Islam [20] reported that the households of the northern regions used considerably higher percentage (23%) of biomass fuels for rice parboiling, much higher than the 7% found in this study. The reason may be that farmers in that region parboil rice for commercial purposes and they also consume boiled rice. However, Miah et al. [14] reported that rural households in eastern region used less than 1% for rice parboiling.

Table 4: Purpose of biomass fuels used by households in the study areas

Household category	**Use of biomass fuels (%)**			
	Well-off	**Middle**	**Poor**	**Mean**
Cooking	72	72	82	75
Boiling	10	10	7	9
Paddy paraboiling	8	7	5	7
Livestock	10	11	6	9

4.4 Fuel consumption and expenditure

The study recorded three types of fuels namely biomass, kerosene and electricity that households used in the study areas (Table 5). The latter two fuels were used for lighting. Although they had access to electricity, but only 70% and 30% households of middle and poor category, respectively used electricity. The reasons may be that electricity was expensive and there were official constraints to obtain electricity connection which for poor households was difficult to perform. Mean monthly expenditure for total fuels was US$ 18.9, 14.4 and 10.6, respectively for well-off, middle and poor households (Table 5), the differences differing significantly (df=2, F= 28.39, P<0.01) among three household categories. It can be inferred that well-off households having more income spend more on high quality fuels (e.g. firewood). Further, the Pearson's correlation test confirmed that household income and household fuel expenditure was positively correlated (R=0.58; P<0.01). The well-off households spent nearly double for fuels than that of the poor. Similar results were reported by Hassan et al. [9] and Miah et al. [14].

Households across three wealth categories spent 68%, 71% and 78% of total fuel costs for biomass fuel indicating that well-offer households paid less for biomass fuels because they gathered maximum biomass from their own sources (e.g. homestead forest, agricultural fields). A negative relationship (R= -0.74, P<0.01) was found between homestead size and fuel expenditure signifying that households with large homesteads purchase less fuels, mainly of biomass. Further comparing total household income and fuel costs then it can be seen that poor, middle and well-off households spend 16%, 12% and 7% of their total income for buying fuels, respectively.

Table 5: Consumption of fuels per month by the households in the study areas

Fuel type	**Household category**		
	Well-off	**Middle**	**Poor**
Biomass (ton)	0.42(13.5)	0.34(11.0)	0.28(8.3)
Kerosene (l)	2(1.3)	2(1.3)	3(1.9)
Electricity (kw-hr)	74(4.1)	42*(2.1)	6**(0.4)
Total cost (US$)	18.9	14.4	10.6

Note: Figures in parenthesis indicate cost (US$);
* represents 70% and ** represents 30% households

4.5 Problems reported by the villagers

More than 90% poor respondents said that they face acute shortage of biomass fuels particularly in rainy season. They also mentioned that due to degradation of public Sal forest they had to travel long distance 2-3 km to collect biomass fuels. Respondents of middle and well-off households reported that fragmentation of homesteads impose on sustainable supply of fuels. Another potential problem that we noticed was the extensive use of traditional cooking stoves. In the study areas we found that more than 50% households across three wealth categories used traditional cooking stoves both one and two mouth (Fig. 3). Women build these stoves with mud at their homes with no cost. Women commented that traditional stoves need more fuels for cooking and generate more smokes. The kitchen environment becomes polluted. The smokes caused eye burning and tearing, headache and very often create problem with breathing. Combustion of wood, dung, and crop residues results in indoor air pollution and directly causes severe human health impacts to the users, mostly rural women and children [23]. In order to reduce biomass fuel consumption and to improve the kitchen environment, 27% well-off households were using improved cooking stove (*bondhu chula*) (Fig. 3).

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 537-544*

Bondhu chula, developed by Bangladesh Council of Science and Industrial Research (BCSIR), combines the feature of a chimney to vent the smoke and designed to burn biomass fuel more efficiently and can save 50-60% fuel, less prone to indoor air pollution and user friendly with compared to traditional cooking stoves [24]. Women who were using *bondhu chula* said that the kitchens remain clean with less black smokes, requires 15-20% less biomass and cook their food quickly. The respondents were asked whether they were interested to shift from using traditional stoves to improved stoves. About 83% of well-off households commented that they would like to change their traditional stoves if they were provided with improved stoves. In contrast 65% and 40% respondents of middle wealth and poor households respectively expressed willingness to use improved cooking stoves. However, they commented that improve stoves were not available in their area and they did not know much about improve stoves.

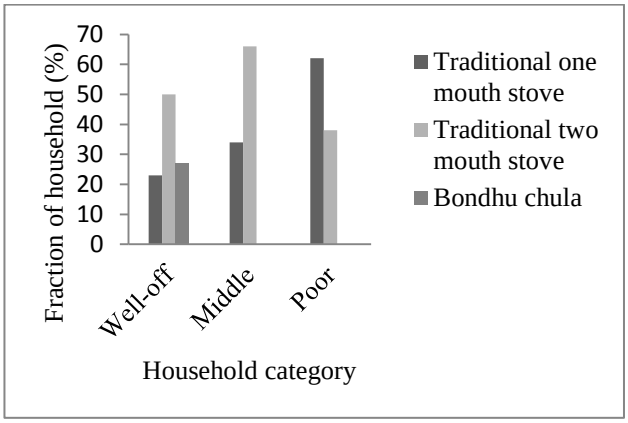

Fig.3: Types of biomass cooking stove used by the households in the study areas

5. CONCLUDING REMARKS

In degraded Sal forest areas of Bangladesh, traditionally firewood is the principal type of biomass fuel. Increasing population pressure would demand more firewood indicating that there might be more pressure on homestead forests and on nearby public forests. Population growth causes land fragmentation in rural areas meaning that homestead forest size and their tree density will be decreasing day by day. Moreover, use of agricultural residues and cow dung as biomass fuels would have negative consequences on land fertility and hence on agricultural productivity. The combined effect will be on rural poverty, mostly on poor segments of the society. It has been reported that more than 1 billion of the world's females whose poor families must rely on fuel wood and dung for cooking and heating have no hope of rising out of poverty as long as this solid fuel dependency persists [25]. As fuel-collectors and cooks, women will face serious health problems caused by indoor pollution due to their direct contact with traditional fuels [26].

In order to improve this situation we need to explore suitable alternative fuel types.

A way to improve the fuel shortage situation might be to increase firewood production by encouraging the establishment of more plantations. With the assistance (for example, free planting materials and technical support) from the forest department (FD) and non-government organizations (NGOs), villagers can be motivated to plant fuel wood species on their available vacant land. Villagers can also be involved in community forestry programs being implemented by the FD or NGOs where they will get a ratio of benefits. Unused public land (e.g. roadside and canal bank) can be planted with fuel wood species under community forestry programs.

Another way to improve fuel situation might be to motivate villagers on use and benefits of improved cooking stoves. However, relevant authorities (e.g. NGOs, concerned government agencies) need to ensure that such stoves are readily available at reasonable price. Authorities may supply subsidized stoves and provide training to local people on construction of stoves. Improved stoves would reduce dependency on traditional biomass and reduce health risks. Upesi stoves (cleaner, more fuel efficient, faster cooking stoves, designed and disseminated in Kenya) have not only created savings in fuel consumption and time for women, but have also created a greater awareness that energy and soil conservation are central to environmental sustainability [26, 27 cited in 26].

There is growing interest in trading carbon offsets from improved stove programs in carbon markets for voluntary reductions, or as part of the Clean Development Mechanism (CDM) of the Kyoto Protocol [28]. Most clean cooking fuel options lead to less greenhouse gas emissions than cooking with coal or biomass and the climate mitigation costs for such investments will often be less than for typical climate mitigation options in industrialized countries [23]. Bangladesh has considerable potential for CDM projects particularly in sustainable energy projects under the CDM scheme [29]. If improved cooking stove programs can be brought under CDM project then it can be hope that forests will be conserved, environment will be less polluted and villagers will have financial incentives along with a sustainable supply of rural biomass fuels.

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