Assessment of Rice Husk Briquette Fuel Use as an Alternative Source of Woodfuel

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Abstract- Biomass is predominantly used in a very traditional way of conversion and causing wastage a lot of energy. Thus creates an extra pressure on the forest biomass to meet the shortage of woody biomass fuel. This study is carried out to find out the alternate resource of woody biomass fuel, to quantify the amount of wood fuel replaced by the woody biomass, reduction of deforestation as well as reduction of carbon dioxide emission, and financial viability analysis of fuel switch. Rice husk briquette use is found to be a viable replacement for wood fuel. Improved rice parboiling system and rice husk briquette machine are found to be financially viable with a cost benefit ratio of 1.57 and 1.06, respectively. The analysis of fuel switch from wood fuel to rice husk briquette analysis showed a negative cost of CO_2 reduction, which means no addition cost is required to adopt briquette fuel. There is a potential of 2.85 million tonne of rice husk briquette production in the country in 2012 that could substitute about 4.66 million tonne of wood fuel. The wood fuel switch to rice husk briquette could save 24.14 thousand hectares equivalent of forest land from deforestation process annually; it could develop a carbon sink equivalent to 1971s' stock by 2030. As a results, a reduction of deforestation process would develop a carbon stock in the existing forest leading towards a sustainable development of forest resources in Bangladesh.

Keywords Rice husk briquette, wood fuel, deforestation, carbon sink, cost of CO_2 reduction.

1. Introduction

Bangladesh is identified to be the most climate vulnerable country in the world. It experiences frequent natural disasters, which causes loss of life, damage to crops, economic assets and infrastructure that adversely impacts on livelihoods on poor people [1, 2]. The country is most vulnerable to sea-level rise of climate change effect. If the sea level is raised by one meter above the present mean sea level then about 40% of land area will go under sea water [3]. To combat the climate vulnerability, it is the right time to take necessary steps for mitigation of greenhouse gas emission. Government of Bangladesh has approved the climate change strategy action plan 2009 addressing a holistic approach of low carbon development and mitigation of greenhouse gas emission [2]. Greenhouse gas (GHG) emission reduction has been taken as a big challenge in last Conference of the Parties (COP) in Paris in 2015. The Paris agreement has emphasized undertaking activities to reducing GHGs emission from deforestation and degradation of forest, and increment of forest carbon [4].

Energy consumption is fairly small, 250 kgOE (kilogram oil equivalent) per capita per year in Bangladesh, which is far below the world average, 1820 kgOE per year [5, 6]. The country is highly populated with 1020 persons per square kilometer having total population of 150.6 million. About three fourth (74%) of country population used to live in rural area [7]; biomass is the main source of energy there; accounting 88% to 98.3% of energy supplied from this source for cooking [8, 9]. There is an imbalance situation between supply and demand of biomass resource, demand is more than the supply, as a results it is being harvested in an unsustainable manner exceeding its' regenerative limits. An acute shortage of wood fuel is being observed in Bangladesh, and it increased from 2.1 to 2.9 million cubic meters during the period of 1996 to 2005 [10, 11]. The estimated total cooking fuel requirement was about 36.5 million tonne in 1999 [12] and increased to 61 million tonne in 2012 [13] in Bangladesh. Out of total biomass energy 7.8 million tonne came from wood fuel from forest and homestead sources and the rest amount came from agro-waste, rice husk, animal dung etc. [7].

A shortage in biomass fuel supply has been observed in urban areas, small entrepreneur, tea stall, restaurants and rural areas. The shortage is met by harvesting wood fuel form the forest. As a result, Bangladesh is approaching deforestation process. There is 6% of dense forest of total area of Bangladesh. The forest area decreased from 1.967 to 1.442 million hectare during the period of 1995 to 2006 at a decreasing rate of 2.86% [11, 14]. However, per capita forest land is about 0.02 ha and the deforestation rate is 3.3 percent annually [15]. Exploration of firewood is one of the major factors causing the deforestation in Bangladesh [16]. The extra pressure on the forest of Bangladesh contributes to the global warming.

Rice husk energy could play a vital role to reduce the gap between the supply and demand of wood fuel. Rice husk contributes a significant share of total biomass energy used in Bangladesh. Rice husk is a by-product obtained from rice milling industries having good fuel properties. This biomass amounts to 10.0 million tonne produced in 2012 [17]. It is mainly consumed as fuel for parboiling and drying processes of paddy in rice mill and some portion of husk is used for making briquette fuel. In Bangladesh, the annual estimated consumption of rice husk energy is 3.44 million tonne (48.2 million GJ) in 2000 and this amount will increase to 6.61 million tonne (92.5 million GJ) in 2030 [18] for rice parboiling and drying at present system of rice processing. Rice husk briquette fuel has got popularity as a viable replacement of wood fuel [19, 20]. A case study showed environmental impact of rice husk briquette use for a district town of Bangladesh and reveals that it has a potential to save wood fuel [21]. However, there is no comprehensive and integrated study on rice husk conversion process and end-use level: rice husk burning in rice processing industries, rice husk briquette production, and fuel switch from wood fuel to briquette; impact of associated GHG reduction on deforestation process. This study will minimize the above knowledge gap by assessing the rice husk saving from existing combustion process; rice husk briquette fuel production process; switch from wood fuel to rice husk briquette fuel; its' impact on GHG reduction and reducing deforestation as well; and financial viability and economic analysis of the technologies.

2. Materials and Methods

2.1. Development of concept for reduction of deforestation

In this study a conceptual model is developed that if the availability of rice husk increases in biomass fuel market the wood fuel gets fall in demand as a result extra pressure on deforestation decreases and forest can stand with sustainable carbon sink. The conceptual diagram of low carbon emission by implementing the improved rice husk energy conversion technology is shown in Fig. 1.

At present rice husk energy is consumed predominantly for parboiling and drying of raw rice in the rice milling industries in Bangladesh. Rice husk is used as fuel to produce steam and hot air. The combustion product, carbon dioxide, obtained from furnace exhaust is renewed by rice plant during the next vegetative period. A rice plantation has a rotation period of 100-150 days. Therefore, the rice husk energy is produced and renewed twice in a year easily. Present system of rice husk energy consumption is close loop cycle shown in Fig. 2(a). As a developing country there is a huge demand of woody biomass fuel in Bangladesh. The fuel wood is exploited from an unsustainable forest of Bangladesh. Therefore, an extra million tonne of carbon dioxide is emitted to atmosphere due to burning of wood fuel obtained from the deforestation process. The present cycle of wood fuel is an open loop cycle shown in Fig. 2(b).

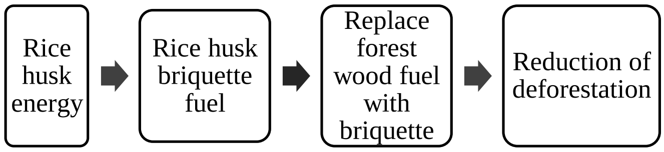


Fig. 1. Conceptual diagram for reduction of deforestation

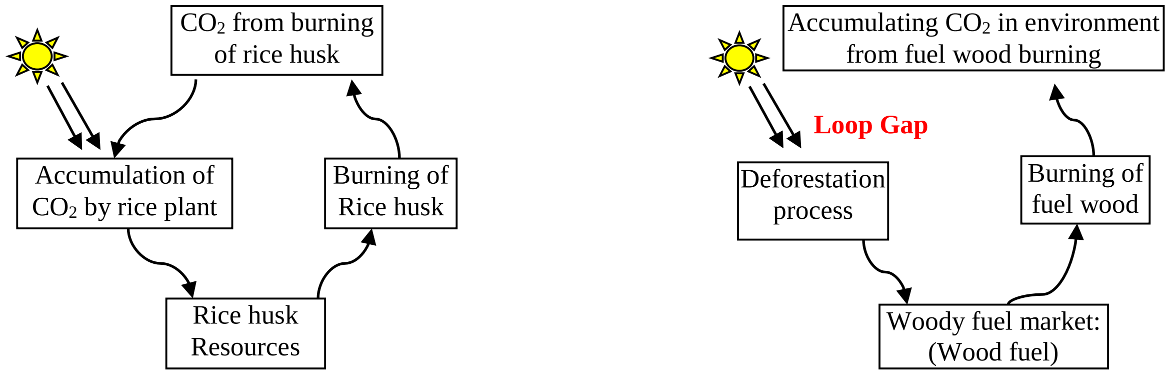
This study intends to establish a linkage between the wood fuel market and rice husk briquette fuel. A portion of wood fuel demand will be met by the rice husk briquette. As the rice husk briquette will replace the wood fuel, therefore, it will help to protect a portion of forest from the deforestation process. In this new approach the undisturbed portion of forest will continue to accumulate the carbon dioxide from the environment. As a result, a carbon sink will be developed and the deforestation process turns into the sustainable forest. The linkage between rice husk energy cycle and the wood fuel cycle is shown in Fig. 3. There are three close loops of carbon cycle observed in the new approach. The first loop is for the existing cycle of rice husk energy with a new burning technology of rice husk (LOOP 1). The new burning technology of rice husk can be an improved version of existing one that can save additional amount rice husk and enters into the wood fuel market [22]. The second loop is for the existing wood fuel cycle with reduced consumption of wood fuel (LOOP 2). Finally, the third loop is for rice husk briquette fuel (a subsidiary loop of rice husk energy). In this loop rice husk briquette reduces the pressure on wood fuel and thus reduces the emission from wood fuel and this gap is filled up by the use of husk briquette. The emission from rice husk briquette is captured by re-growing rice plant during the next vegetation period. On the other hand, the untouched portion of the forest captures the carbon emitted from fuel wood. In this way, a sustainable forest will start to grow.

2.2. Development of mathematical expression

Consumption of rice husk (RH) is calculated as Eq. (1)

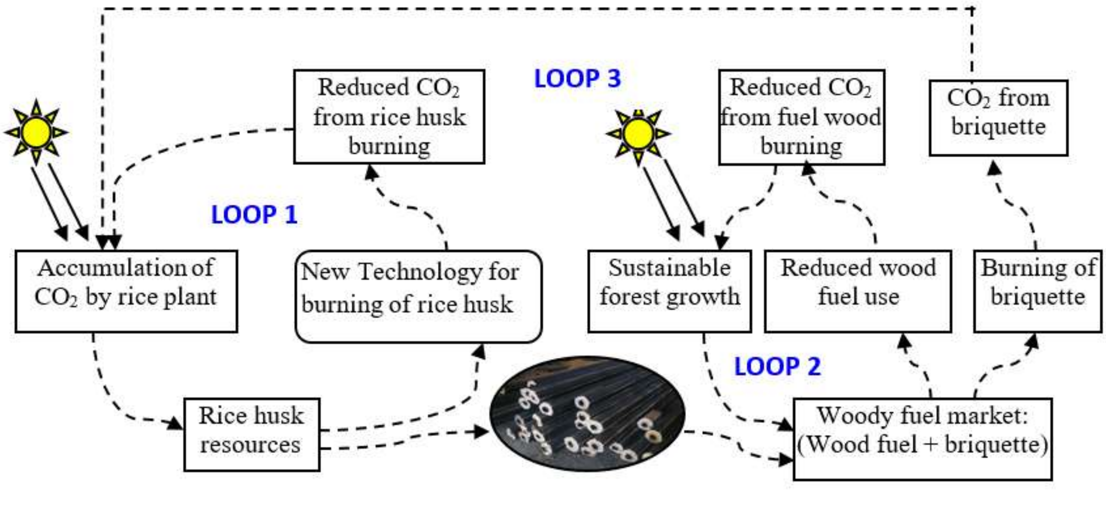
$$RH_{present\_consumption} = RH_{production} \times C_f \quad (1)$$

Where, C_f = consumption factor (0.67), the portion of total husk production consumed in rice parboiling system [23].



(a) Rice husk energy life cycle (b) Wood fuel cycle

Fig. 2. Existing system of (a) rice husk cycle and (b) wood fuel cycle



Rice husk energy life cycle Rice husk briquette Wood fuel life cycle

Fig. 3. Showing diagram for reduction of deforestation by rational use of husk energy

Husk consumption at new situation at reduced rate is calculated as Eq. (2)

$$RH_{reduced\_consumption} = RH_{present\_consumption} \times E_{f\_present} / E_{f\_improved} \quad (2)$$

Where, $E_{f\_present}$ = 20%, the efficiency of present combustion system; $E_{f\_improved}$ = 40% the efficiency of improved combustion system [22].

Quantity of surplus amount of rice husk after intervention of new technology is calculated as Eq. (3)

$$RH_{surplus} = RH_{present\_consumption} - RH_{reduced\_consumption} \quad (3)$$

The surplus amount of rice husk is converted into compressed briquette fuel. The briquette fuel will replace a portion wood fuel. The quantity of rice husk briquette is calculated as Eq. (4)

$$Q_{RHB} = RH_{surplus} \times R_f \quad (4)$$

Where, Q_{RHB} = quantity of rice husk briquette and R_f = 0.862 mass recovery factor [24].

By combining the Eq. (1) to Eq. (4) a new relationship is found to quantify the rice husk briquette production as Eq. (5)

$$Q_{RHB} = RH_{production} \times C_f \times \left(1 - \frac{E_{f\_present}}{E_{f\_improved}}\right) \times R_f \quad (5)$$

Rice husk briquette fuel has an advantage over wood fuel use. One kilogram of rice husk briquette fuel can provide equivalent service of 1.63 kilogram of wood fuel. The equivalent quantity of wood fuel replaced by the rice husk briquette is calculated as Eq. (6)

$$WF_{replaced} = Q_{RHB} \times P_f \quad 6)$$

By substituting the quantity of briquette in Eq. (5) into the Eq. (6) the new relationship is found as Eq. (7)

$$WF_{replaced\ by\ RHB} = RH_{production} \times C_f \times \left[1 - \frac{E_{f\_present}}{E_{f\_improved}}\right] \times R_f \times P_f \quad (7)$$

Where P_f = 1.63 [19] performance factor of briquette over wood fuel.

Forest area (FA) saved due to the saving amount fuel wood (WF) obtained from equation (7) can be calculated as Eq. (8)

$$FA = WF_{replaced\ by\ RHB} / Y_f \quad (8)$$

Where, FA = forest area ha, and Y_f = yield factor of forest biomass, tonne/ha. The yield factor is considered as 193 tonne/ha [14] of biomass density of forest.

From equation (7) and (8) a new relationship is found as Eq. (9)

$$FA = RH_{production} \times C_f \times \left[1 - \frac{E_{f\_present}}{E_{f\_improved}}\right] \times R_f \times P_f \;/\; Y_f \quad (9)$$

Finally, the reduction of carbon dioxide emission due to substitution of wood fuel from non-sustainable source by rice husk briquette is calculated as Eq. (10)

$$CO_{2\_reduction} = WF_{replaced} \times GWC_{woodfuel} \quad (10)$$

Where, GWCwoodfuel = global warming potential of wood fuel burning

From equation (7) and equation (10) a new relationship is found to calculate the carbon dioxide reduction as Eq. (11)

$$CO_{2\,reduction} = RH_{production} \times C_f \times \left[1 - \frac{E_{f\_present}}{E_{f\_improved}}\right] \times R_f \times P_f \times GWC_{woodfuel} \quad (11)$$

In this study, the existing scenario of the carbon cycle of rice husk is analyzed by using emission factors of the biomass energy. The reduced amount of emission due to intervention of rice husk briquette fuel in wood fuel market has been quantified in this study. The quantity of regeneration of forest is also investigated. The GHG such as CO_2, CO, CH_4, TNMOC and N_2O are accounted in the estimation shown in Table 1 [25, 26]. Rice husk energy is considered as renewable source and wood fuel is considered as non-renewable source.

2.3. Cost-benefit assessment

Economic analysis was done for comparison of new type and existing rice parboiling boiler-furnace, financial viability of rice husk briquette machine, and comparison of woodfuel stove and rice husk briquette stove. This analysis shows the cost of CO_2 reduction due to briquette fuel use to examine viability of its' adoption.

3. Results and Discussion

3.1. Energy balance in Bangladesh

Bangladesh is net energy importer; almost all petroleum energy is imported and it contributes about 50% share of total commercial energy consumed [27]. The petroleum is consumed by the transport, power and agriculture sectors. Natural gas is used in power generation, industrial and residential (cooking fuel in some urban areas) sectors. The rest of the energy needed for large part of the population is supplied from traditional biomass. It contributes about 48% of total energy consumed in the country [27]. Consumption of different biomass energy in 2005 is shown in Fig. 4 [20, 28-31]. Most common biomass used in the country are rice husk, field crop residue, forest wood fuel, jute stick, animal dung, municipal waste, sugarcane bagasse etc.

3.2. Wood fuel situation in Bangladesh

Wood fuel yields about 61% of round-wood considered to be the main forest product in Bangladesh. FRA 2000 reported that country requires about 9.4 million m^3 of wood fuel annually against a capacity of supply of 6.18 million m^3 [11]. The forest area of the country is decreasing day by day [11, 14] whereas; the wood fuel consumption is increasing sharply [27]. The historical data of forest area, wood fuel production and consumption are shown in the Fig. 5 [11, 14, 27]. There is huge gap between the production capacity and actual demand of wood fuel. This gap is met by collecting the wood fuel from deforestation process. It shows that wood fuel is consumed beyond the regenerative limits. Hence the consumption of wood fuel contributes greenhouse gas emission to environment, creates a loop gap shown in the wood fuel cycle (Fig. 2b). To fill up this loop gap it is needed to find out alternative source of wood fuel. In this regard rice husk briquette could be a viable option to fill up the loop gap. The availability and potential of rice husk resource for making compressed briquette fuel are discussed in the next section.

3.3. Rice husk energy resource

Rice husk is the outer cover of rice raw rice grain. The mass share of rice husk is on an average 20% of total mass of grain. Rice is the main base of food for people in Bangladesh. The rice husk production is increasing at ate of 2.35% per year as the rice production increased. The historical data of rice husk production is shown in Fig. 6 [17, 32]. Since the rice husk biomass is increase in trend, therefore, proper planning of rice husk use is needed to achieve a sustainable biomass fuel development.

Table 1. Basics of estimating GHG commitments

GW Potential	1	4.5	22.6	12	290		Heating Value	Non-biogenic emission	Biogenic emission
	Emission factors on energy basis (g/MJ)								
Fuel Type	CO_2	CO	CH_4	TNMOC	N_2O	GWC	MJ/kg	CO_2eq kg/kg fuel	CO_2eq kg/kg fuel
Fuel wood	90.7	4.34	0.26	0.53	0.0059	124.17	15.12	1.877	
Crop Residues (rice husk)	84.5	3.74	0.41	0.72	0.0169	34.76	13.03	0.453	1.101

GWC: Global Warming Commitment = Σ GHGi x GWPi; GWP = global warming potential, TNMOC = Total non-methane organic compound; GWC of fuel wood = 90.7 x GWP_{CO2} + 4.34 x GWP_{CO} + 0.26 x GWP_{CH4} + 0.53 x GWP_{TNMOC} + 0.0059 x GWP_{N2O} = 124.177; GWC of rice husk fuel = 3.74 x (GWP_{CO}-1) + 0.41 x (GWP_{CH4}-1) + 0.72 x (GWP_{TNMOC}-1) + 0.0169 x GWP_{N2O} = 34.767; Adapted from [25, 26].

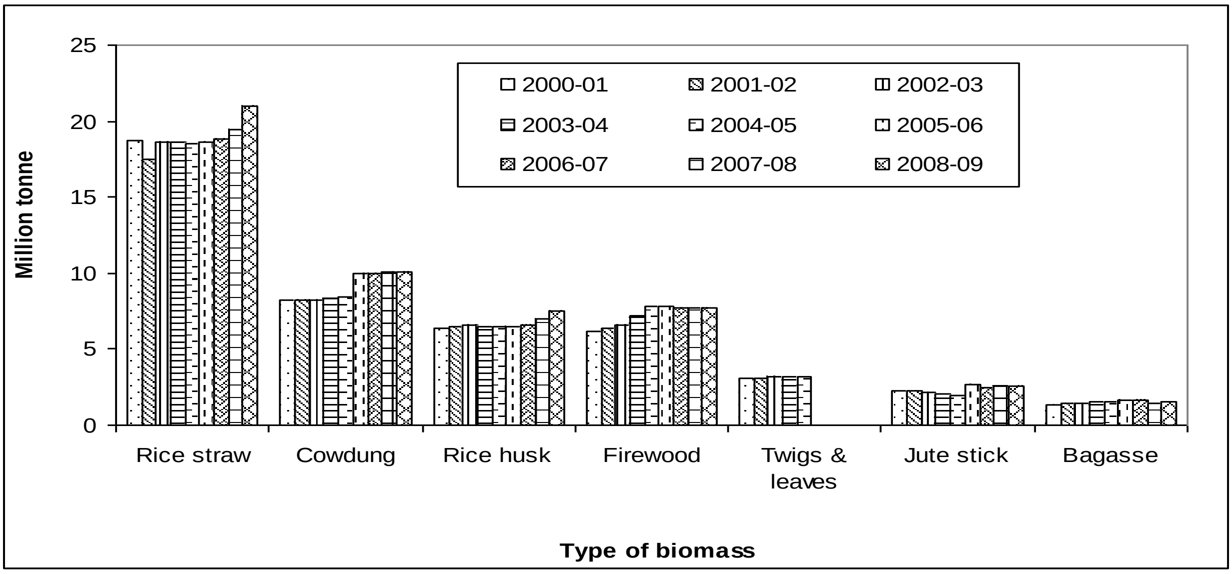


Fig. 4. Traditional biomass supply in Bangladesh [20, 28-31]

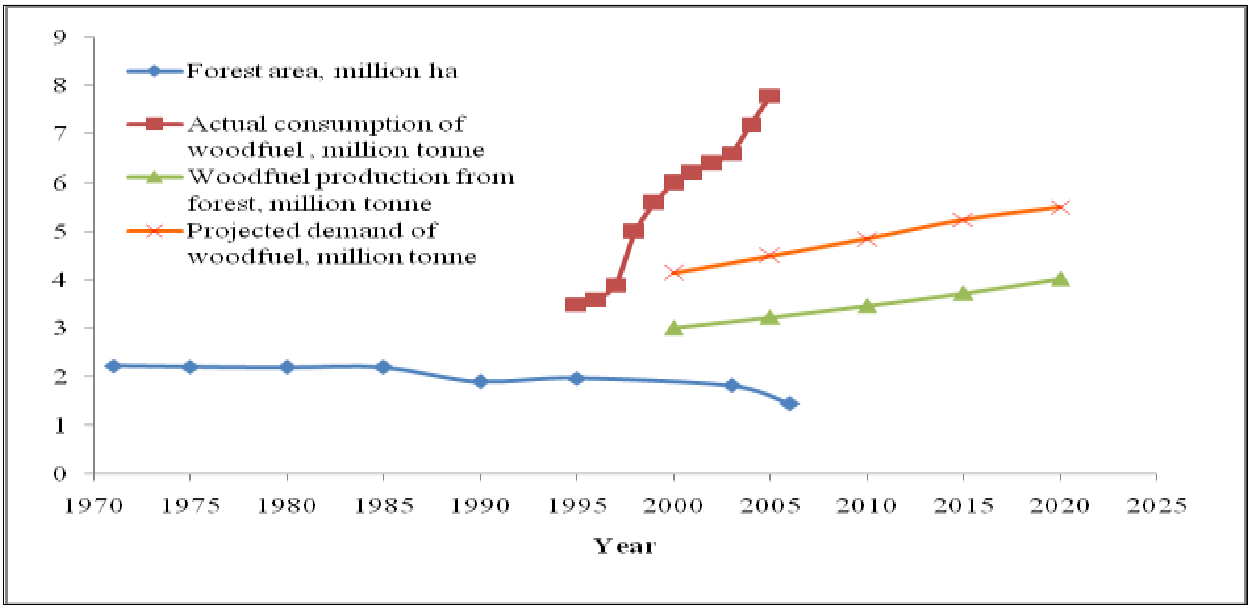


Fig. 5. Historical data of forest area and wood fuel consumption and production [11, 14, 27]

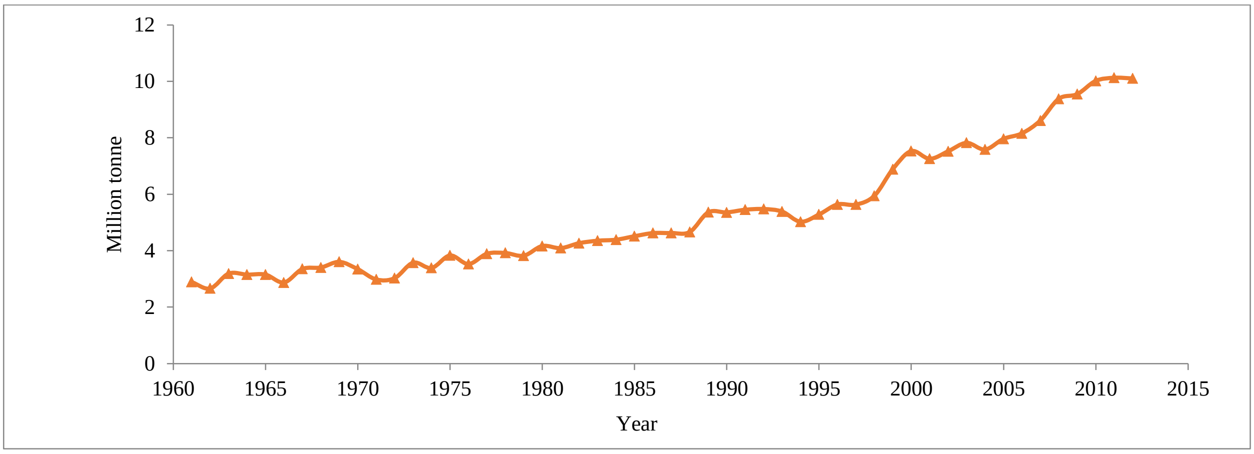


Fig. 6. Historical data of rice husk production in Bangladesh [17, 32]

3.4. Present use of rice husk energy

Rice husk is the major industrial biomass energy used in agro-industrial sector. Thermal energy is used to process 50 million tonne of rice in the sector. At present Bangladesh produces over 10.05 million tonne (Mt) of rice husk biomass. Out of this about 6.73 Mt is used for rice processing (Fig. 7a), 1.67 Mt is used for briquette production (Fig. 7b) and the rest amount is used for some non-energy purposes. Carbon dioxide produced due to the burning of rice husk is renewed by the rice plant in next growing season. The life cycle of rice husk is a close loop cycle (Fig. 2a). The rice husk is burnt in a very inefficient boiler to produce steam in rice milling industries. At present rice husk is burnt in an inefficient furnace used in rice mill. The thermal efficiency of the rice husk boiler can easily be increased to 40% by making some improvement in rice husk parboiling system. Such technology already has been developed by Bangladesh Rice Research Institute under technical cooperation of German Technical Cooperation and has been showing satisfactory performance since 2008 [22]. By introducing the improved rice parboiling technology about 3.31 million tonne of rice husk can be saved and the GHG emission level can be reduced from 12.53 million tonnes of CO_2 equivalent to 5.76 million tonnes of CO2 equivalent (Table 2).

3.5. Rice husk briquette fuel production scenario

Rice husk biomass remained after the completion of rice parboiling and drying process is used to make compressed briquette fuel. This rice husk briquette is dry biomass having a calorific value in the range of 14.2 to 17.5 MJ/kg [33]. It produces less smoke and burns slowly compared to fuel wood. It is used as an alternative to fuel wood for cooking purposes. The performance of briquette fuel is better than wood fuel. One kilogram of rice husk briquette can provide same service of 1.63 kilogram of wood fuel during cooking purposes [19]. The briquette fuel production can be increased by ensuring the surplus of rice husk when a new technology for rice husk burning is introduced shown in the LOOP 1 of the life cycle diagram (Fig. 3). A scenario of rice husk briquette production is analyzed and shown in Fig. 8. Rice husk briquette is expressed in terms of wood fuel equivalent.

3.6. Impact of rice husk briquette on wood fuel supply

Rice husk briquette would reduce fuel wood fuel demand and reduce harvesting fuel from forest. When the rice husk briquette fuel enters in wood fuel market, it reduces the volume of wood fuel from market. As a result, volume of wood fuel reduces share of wood fuel from non-sustainable source and help develop a sustainable forest. The combined amount of rice husk briquette and sustainable fuel wood would be able enough to meet the actual demand (Fig. 9). Total 4.66 million tonne of wood fuel could be substituted from wood fuel market in 2012 thus saves the forest (Table 3).

(a) Rice husk is burnt to produce steam in rice mill

(b) Rice husk briquette fuel production

Fig. 7. Showing rice husk used in (a) parboiling process and (b) husk briquette fuel production

Table 2. Reduction of rice husk consumption by using improved parboiling system and reduction CO_2 emission in 2012

Total husk consumption, million tone		Total CO_2e million tonne/yr (existing system)		Total CO_2e million tonne/yr (improved system)		Reduction of CO_2e million tonne/yr	
By existing system	By improved system	Non-biogenic	Biogenic	Non-biogenic	Biogenic	Non-biogenic	Biogenic
6.63	3.32	3.23	8.30	1.61	4.15	1.62	4.14

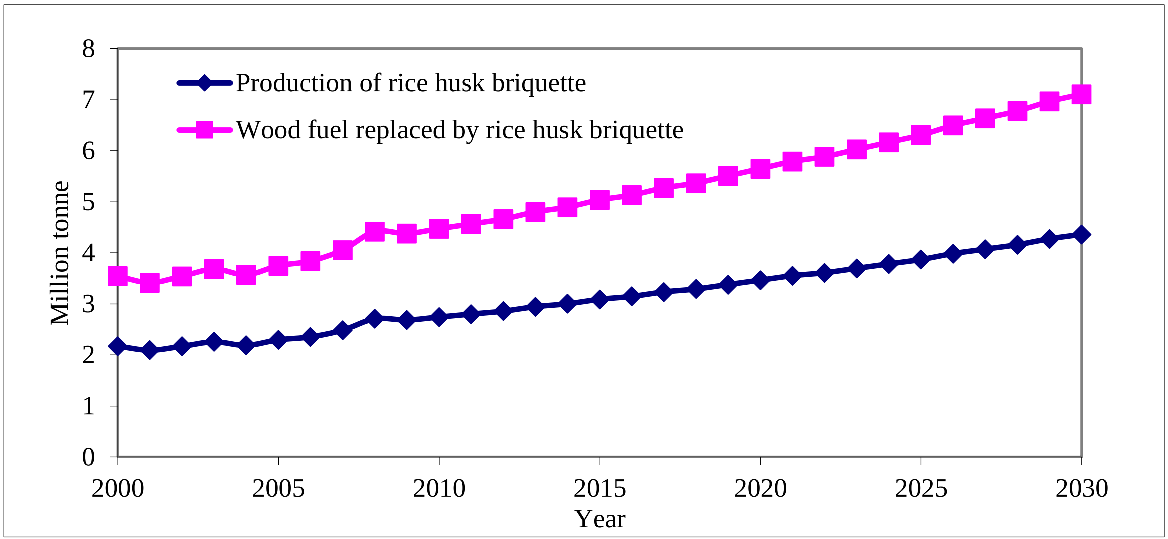


Fig. 8. Scenario for rice husk briquette production potential to replacement of fuel wood

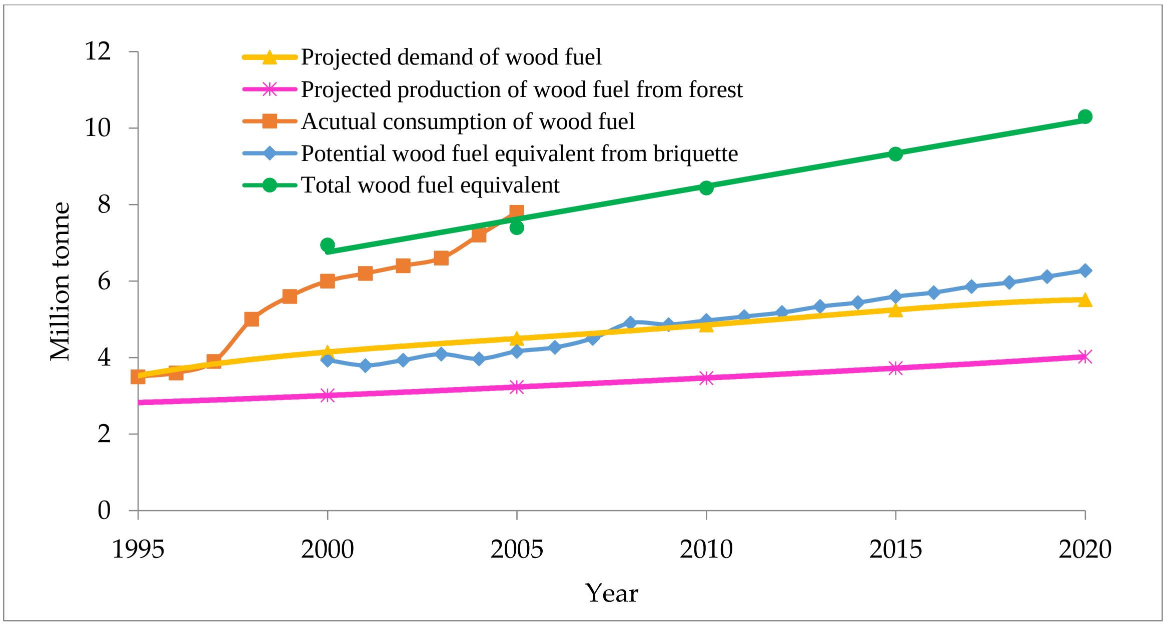


Fig. 9. Impact of share of rice husk briquette on supply of total wood fuel equivalent

3.7. Reduction of deforestation and CO_2 emission

Wood fuel consumption is reduced due to the intrusion of rice husk briquette in wood fuel market as briquette is used as alternative of wood fuel. The estimated wood fuel replaced by the briquette fuel (Fig. 8) is considered remained untouched in the forest. The briquette fuel could save about 24.14 thousand hectares equivalent of forest land annually. The biomass of this forest creates carbon sink by renewing 7.45 million tonne of CO_2 equivalent annually (Table 3). The scenarios of potential reduction of deforestation and reduction of carbon dioxide are shown in Fig. 10. The carbon dioxide emission reduction is estimated to be 5.66 million tonnes in 2000 and increased to 11.36 million tonnes in 2030. The forest area developed under the scenario is 18.35 thousand hectares in 2000 and this would increase to 36.82 thousand hectares in 2030. The impact of reduction of deforestation on the total forest area of Bangladesh is analyzed. The forest area saved is estimative based on equivalent wood fuel replaced by briquette fuel each year and cumulated scenario of forest area in future is shown in Fig. 11. The scenario shows total forest area would increase to 2.20 million hectares by 2030 which would be equivalent forest are that was in 1971. Therefore, a sustainable growth of forest could be achieved if rice husk briquette fuel is used as viable replacement of wood fuel.

Table 3. Production of rice husk briquette and reduction of deforestation in 2012

Production of rice husk briquette, million tonne	Quantity of wood fuel replaced by briquette, million tonne	Reduction of CO2 emission, million tonne	Reduction of deforestation, 000 hectare (ha)
2.85	4.66	7.45	24.14

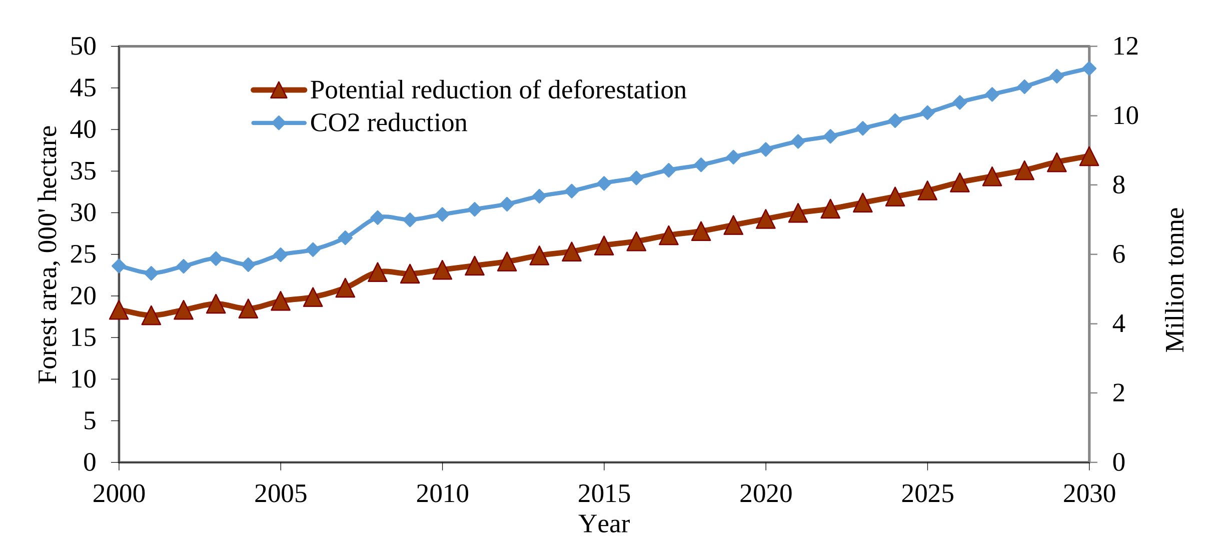


Fig. 10. Reduction of deforestation and carbon dioxide emission due to the intervention of rice husk briquette in wood fuel market

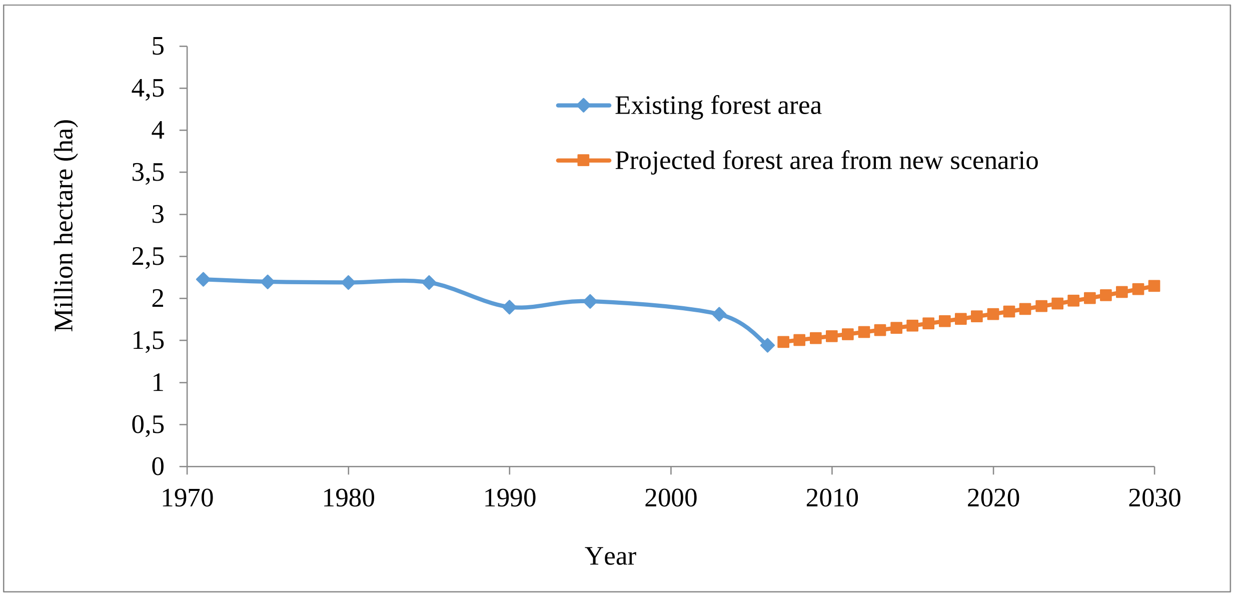


Fig. 11. Potential increase of forest area in Bangladesh

3.1. Cost-benefit assessment

Financial viability of rice husk as alternative fuel use explains three different level of technologies: i) new technology for rice parboiling, rice husk briquette production, and iii) rice husk briquette consumption instead of wood fuel at end-use level. Firstly, new technology for rice parboiling boiler shows lower running cost (BDT 1.44 million/year) compared with existing one (BDT 2.35 million/year). Life cycle cost for each tonne of paddy parboiled were found to be BDT 156.00 and BDT 244.00 for new and existing parboiling boiler, respectively. The analysis also shows benefit-cost ratio of 1.57 with a pay-back period of 6 months only (Table 4).

Secondly, rice husk briquette machine was found to be financially viable. The analysis shows total revenue of BDT 2.55 million/year, whereas, total running cost of BDT 2.36

million/year. It also shows a benefit-cost ratio of 1.06 and a pay-back period of 1.57 year (Table 5).

Thirdly, economic analysis of wood fuel and rice husk briquette use at end-use level shows a significant amount of CO_2 saving by rice husk briquette user compared with wood fuel one (Table 6). The life cycle cost analysis shows and negative cost of CO_2 reduction (BDT -34.46/tonne of CO_2 reduced) means no additional cost is required to replace wood fuel with rice husk briquette stove, which clearly indicates that use of rice husk briquette fuel as an alternative to wood fuel is a financially viable option.

Table 4. Partial budget for new type rice parboiling boiler and existing one

Particulars	Improved technology	Existing technology
Capital cost, BDT*	500000	200000
Number of batch/year	300	300
Husk consumption kg/batch	900	1800
Electricity consumption kWh/batch	10	-
Labour wage, BDT/batch	1500	1500
Electricity price, BDT/kWh	6	-
Husk price, BDT/kg	3.5	3.5
Husk cost, BDT/year	945000	1890000
R & M cost, BDT/year	25000	10000
Total running cost, BDT per year	1438000	2350000
Life time, year	10	10
Discount rate, %	10	10
Cost of parboiling, BDT per tonne paddy	156	244
Benefit-cost ratio	1.57	
Pay-back period, month	6	-

Table 6. Cost analysis comparison between wood stove and rice husk briquette stove

Particulars	Wood stove	Briquette stove
Stove installation cost, BDT	1000	2500
Stove life time, year	5	5
Discount rate, %	10%	10%
Stove efficiency, %	21%	27%
Annual fuel consumption, kg	36308	22275
Repair and maintenance cost, BDT/year	200	200
Fuel price, BDT/kg	5.00	8.0000
CO2 emission, kg/kg [25]	1.877	0.4530
Total CO2 emission over life, kg	340753	50453
CO2 emission reduction over life time, kg	0	290300
Life cycle cost of CO_2 reduction, BDT/tonne		-34.46

Table 5. Partial budget for rice husk briquette machine

Particulars	
Capital cost, BDT	300000
Life time, year	15
Discount rate, %	10
Electricity consumption, kWh/tonne-briquette	145.2
Operating hour/day	12
Operation days/year	350
Labour wage cost/day	1200
Screw required, nos./year	5
Screw price, BDT/piece	1200
Screw repair cost/day	100
Heater required, nos./year	4
Heater, price BDT/piece	6500
Average briquette production kg/hour	93.55
Mass recovery, %	90%
Husk price, BDT/kg	3.5
Electricity price, BDT/kWh	6
Die barrel required nos./year	6
Barrel cost, BDT/piece	1000
Price of briquette, BDT/tonne	6500
Total revenue, BDT/year	2553915
Total running cost, BDT/year	2363287
Benefit-cost ratio	1.06
Pay-back period, year	1.57

*BDT = Bangladeshi Taka

4. Conclusions

Biomass contributes lion share of rural energy in Bangladesh. At present the biomass is consumed in traditional conversion way and causes wastage. Biomass demand increases due to the growth of extra millions of population each year and creates an extra pressure on forest. Improved use of rice husk energy could meet a significant amount of wood fuel demand that could reduce extra pressure on forest. There is a potential of 4.66 million tonne wood fuel substitution by rice husk briquette thus saves 24.14 thousand hectares equivalent of forest land annually. This forest creates carbon sink by renewing 7.45 million tonne of CO_2 equivalent annually. The economic analysis at three different technological changes (improved rice husk combustion boiler, rice husk briquette production, and wood fuel replaced with briquette) shows financially viable. A negative cost of CO_2 reduction clearly indicates the technology could be adopted without addition cost involvement. Hence the use of rice husk briquette would reduce deforestation process and develop a carbon stock towards a sustainable growth of forest resources in Bangladesh.

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