Potential of peatlands in Bangladesh and sustainable management strategy

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Abstract: Peat is an unconsolidated deposit of semi-carbonized plant matter. Peat is usually found in water-saturated environments and has certainly high moisture content. *Haors* are peat-dominated areas in Bangladesh, which hold the largest peat reserves of the country. Peat is one of the most important mineral resources worldwide. For the utilization of peat similar to other countries, it is necessary to know its energy and fertility potential and develop a sustainable management strategy for peatlands in Bangladesh. This study mainly focused on the heating and fertility potentials of peat in Bangladesh and on strategies to sustainably manage these peatlands. This study was carried out in the *haor*-based *Katiadi* and *Mohanganj* upazilas in the *Kishoreganj* and *Netrokona* districts of Bangladesh, respectively. These two *haor* areas are appropriate for collection of peat samples and people in those areas use peat as fuel and fertilizer. After peat samples were collected, they were tested in several laboratories such as the Agrivarsity Humboldt Soil Testing Laboratory of the Bangladesh Agricultural University (BAU) and Institute of Fuel Research and Development (IFRD), Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, Bangladesh. These laboratories are suitable to find out the physical and chemical properties of peat. Based on the physical and chemical analysis of the collected peat, it has heating and organic fertility potentials. In this study, the pH; organic matter; N, P, K, and S contents of the peat were analyzed. The calorific value of peat (2638 $kcalkg^{-1}$) is higher than that of cow dungs (1797 $kcalkg^{-1}$) and rice husk briquettes (2546 $kcalkg^{-1}$).Minor-scale rural *haor* communities use peat as domestic cooking fuel and supply for small agrofarms. In some agrofarms, ingredients, such as animal manure, are mixed with the peat to balance organic fertilizer. Our analysis indicates that peat might be used for different purposes, especially for brick fields, which reduces deforestation and saves the environment. The Government of Bangladesh should design a major peat development program to determine systematic approaches for the sustainable use of peat and peatlands in Bangladesh.

Keywords: *Haor*, peat, heating potential, organic fertilizer, peatland management, Bangladesh

Citation: Ali,M. R., M. R. Islam, M. H. Islam, K. Osamu, and M. Kosuke. 2020. Potential of peatlands in Bangladesh and sustainable management strategy. Agricultural Engineering International: CIGR Journal, 22 (4):65-74.

1 Introduction

Bangladesh is a delta with an area of 14.757 million ha, which formed by the rivers Ganges and Brahmaputra. Bangladesh has three major physiographic units, that is, floodplains, terraces, and hills, which cover ~80%, 8%, and 12% of the area, respectively (Bhuiya, 1987). The effectiveness of puddling depends on soil characteristics such as texture, the clay minerals predominating, swelling and shrinking, salinity, organic matter content and water control which are the main soil-related constraints significantly affecting the crop production (FAO, 1985). In Bangladesh, peatland covers an area of ~0.22

Receiveddate:2019-09-25 **Accepteddate:**2020-01-09

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miohectares, accounting for 1.6% of the total area of the country. There are three categories of peat soils in Bangladesh: sapric peat, hemic peat and fibric peat (Uddin and Mohiuddin, 2019).Peat deposits can be found at shallow depths in different low-lying areas of Bangladesh. The major deposits are situated in the greater districts of Faridpur, Khulna, and Sylhet. Apart from the peat deposits in these districts, small scale peat reserves are also located in the Maulavibazar, Netrokona, Kishoreganj, and Brahmanbaria districts of Bangladesh (Maitra et al., 2014).

In haor and beel or low-elevation regions of Bangladesh, peatlands are formed by the process of deposition of organic matter derived from the accumulation of plant debris or decaying vegetation. The peat is thin- to thick-bedded (0.5 m to 8 m), brownish black to black, fibrous, and mature; the chemical analysis of the peat revealed that its heating value and carbon content are high, and its ash and sulfur contents are low (Masum et al., 2014). Worldwide, peat is used for different purposes. Peatlands have been drained for various uses including agriculture, forestry, and peat extraction for energy (Murphy et al., 2015); locally, it is used as heating fuel for power plants, Brickfields, industries, and homes. Peat is also important for farmers and gardeners who seek to improve soil structures for the cultivation of vegetables and fruits. The application of peat in Brickfields and as cooking fuel reduces the deforestation and saves the environment (Masum et al., 2014).

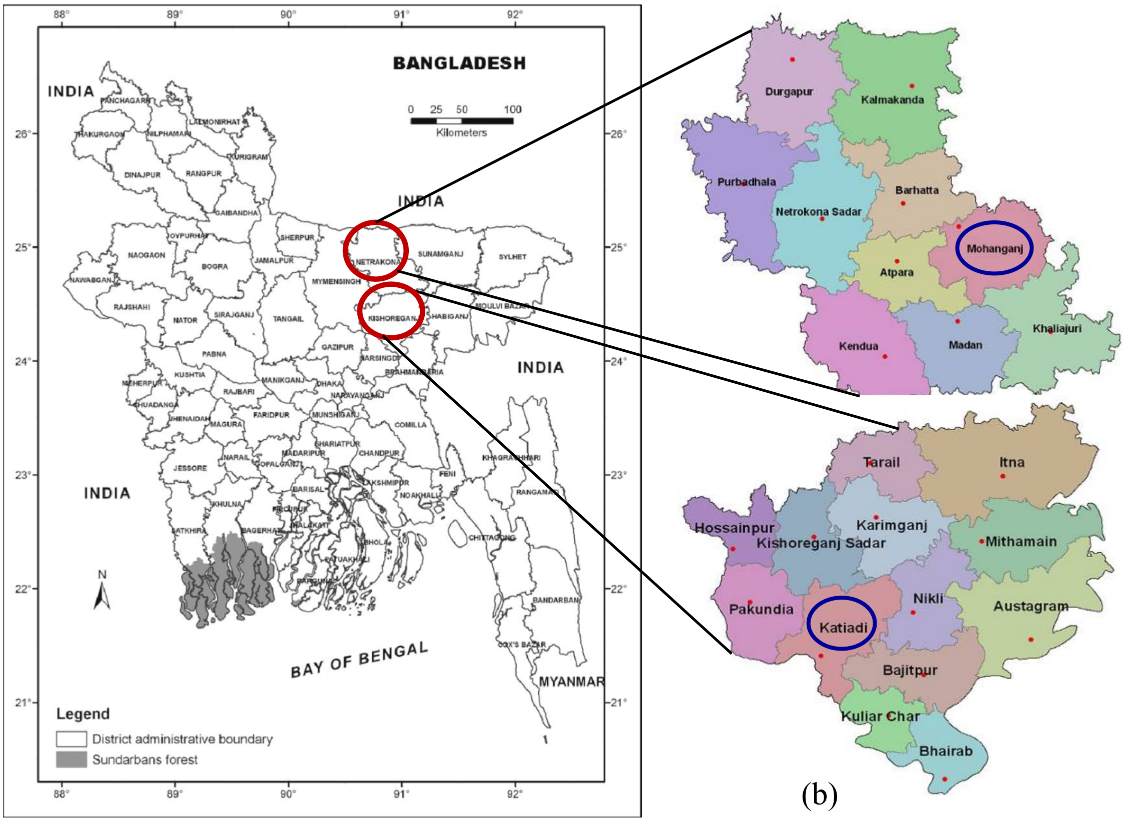
In Bangladesh, *Boro* rice more widely grows in *haor* areas with clay topsoil. Thesesoils contain alternate layers of peat and muck. Peat and mineral layers occasionally occur at the top of the soil profile. Because of the presence of highly and partially decomposed organic matter and sulfur in these soils, there is potential for root injury by the production of H_2S gas. The whole *haor* area goes underwater during the wet season, which represents the earliest stage of the pale environmental.During the dry period, the area becomes dry and vegetation only exists in channel banks, indicating the middle stage of environmental condition (Masud et al., 2011). In this environment, peat is formed in *haor* areas. Locally, these peats are also used for fuel and as fertilizer for vegetable production. Peat utilization is a long tradition in many countries. Well decomposed peat types are used for energy production and less decomposed peat in the surface layers of the peatlands is suitable for agricultural and horticultural purposes. Peat plays a greater role in agriculture as soil improvement additive, fertilizer and horticultural cultivation medium (Cao, 2019)

People in *haor* areas in Bangladesh do not know the characteristics of peat and its versatile use. In the *haor* development master plan, the Government of Bangladesh stated that peat should be extracted from some *haor* areas to meet local and national energy requirements (BHWDB, 2012). The current method of peat extraction is not scientific nor environmentally friendly. Carbon (C) and nitrogen (N) release from peatlands are closely related to water management and soil degradation. Peat degradation has not been explicitly accounted for when estimating national greenhouse gas inventories (Liu et al. 2019). Technical, incentives and regulatory measures must be enhanced to make the best benefits of the use of peatland (Uddin and Mohiuddin, 2019).It is therefore necessary to implement an effective system to protect the environment and properly manage the mineral resources of the *haor* area. It is also necessary to determine the potential of peat soil and informrural people about utilization methods. The present study was undertaken to determine the chemical properties and potential of peat as fuel and fertilizer. The findings obtained in this study will be valuable to establish more effective approaches for the sustainable use and conservation of peatlands in Bangladesh.

2 Materials and methods

2.1Site selection

The *haor*-based *Katiadi* upazila (Latitude: 24°15'0.00"N,Longitude: 90°47'30.12"E) and *Mohanganj* upazila (Latitude: 24°52′0.00″N,Longitude: 90°58′0.00″E) in the Kishoreganj and Netrokona districts of Bangladesh, respectively, were selected for this study for the collection of peat samples and the determination of theirutilization and management by local people. The locations of the Netrokona and Kishoreganj districts and all upazilas of the Netrokona and Kishoreganj districts are shown in the map of Bangladesh in Figure 1.



(a)

(a) Netrokona and Kishoreganj and (b) all upazilas of the Netrokona and Kishoreganj districts

Figure 1 Location of the study areas on a Bangladesh map

2.2 Collection and preparation of peat

Peat samples were collected from selected locations during the dry season (December 2018–January 2019). After the collection, the peat samples were sun-dried and their physical and chemical properties were determined in different soil testing laboratories. In Figure 2 (a), after digging and collecting the peat by farmers, they were dried under open sun drying for using as cooking fuel. In the study peat samples were collected from the farmers' field as shown in Figure 2 (a). In Figure 2 (b), collected peat samples were dried further in front of the laboratory for determining physical and chemical properties.Figure 2 shows the collection of peat from the field and the preparation for drying.

(a) From the field (b) Briquette generation

Figure 2 Collection peat for sun drying

Water content is one of the important factors for reducing the calorific or heating value of peat. For using peat as fuel it is necessary to know the moisture or water content of peat. Calorific value of peat generally varies with moisture content of peat. In the study, before testing the peat in different laboratories, its moisture content (m.c.) was determined using an electric oven at the Department of Farm Power and Machinery, Bangladesh Agricultural University (BAU) in Mymensingh, Bangladesh (Figure3). The peat samples with petri dish were weighted before putting in the oven. For comparison of calorific value of peat with that of cooking fuels common in Bangladesh like cow dung and rice husk briquettes were also collected and weighted for putting in the oven. The samples were kept in an oven at 104°Cfor 24 h.

(a) weighing of samples (b) putting samples in the electric oven

Figure 3 Moisture content measurement

2.3 Laboratory experiment

For using peat as cooking fuel and fertilizer it is necessary to know thephysical and chemical properties including calorific value of peat.The process of peat ignition methods depends on numerous fuel or energy features, i.e. calorific value, chemical composition, moisture content, etc. (Ahmed et al., 2019). The calorific value of peat is also depending on chemical composition. The chemical properties of all collected peat samples were tested in the Agrivarsity Humboldt Soil Testing Laboratory, BAU, Mymensingh, Bangladesh. The calorific value necessary to determine the heating potential of the peat samples was obtained using a bomb calorimeter at the Institute of Fuel Research and Development (IFRD), Bangladesh Council of Scientific and Industrial Research (BCSIR) in Dhaka, Bangladesh. To compare the calorific value of peat (Figure 4c) with that of cooking fuels common in Bangladesh, cow dung (Figure 4a) and rice husk briquettes (Figure 4b) were also collected (Figure4) and tested at the same laboratory. Selected physical properties of the peat were also tested at the Green Energy Knowledge Hub, BAU, Mymensingh, Bangladesh.

(a) Cow dung (b) Rice husk briquettes (c) Peat briquettes

Figure 4 Common dry cooking fuels

2.4 Peat utility status based on a field survey

2.4.1 Peat for the use as cooking fuel

Co-processing of peat with rural biomass can be a potential solution to heat and power for the rural communities/agri-industry that are not connected with national grids and alleviate their waste management problems (Roy et al., 2018). In Bangladesh, peatis used for household cookingin *hoar* or lowland areas.It may be assumed that peat is not prepared for the use as fuel in places in which other cooking fuels are easily available.

A lot of information is available about worldwide peat harvesting. The preparation of peat for year-round burning at home involves several basic approaches, as shown in Figure 5. These approaches are presented here after several visits to *haor* areas and face-to-face interviews of locals. Unlike coal and other fuels on the market, peat requires special treatment, including drying, before it can be used as fuel. Because it is dug from undrained deposits, it contains between 85% and 95% water; drainage rarely lowers the amount below 80% (Davis, 1909). Based on the activities necessary to prepare peat for the use as fuel mentioned in Figure 5, farmers start the digging as early as possible in winter to take advantage of favorable drying conditions in winter and early summer.

Peat digging involves several basic steps: removal of relatively thin layers from the Earth's surface and digging of deep quarries (about 1.5m) to reach the depth of the peat bed. After the selection of peatland, in general, male farmers dig (about 1.5m approximately) the landfor the collection of peat. Women farmers make handmade peat cakes for drying in the field under open sunlight. Depending on the sunlight it takes about 10-15 days to dry. Based on the long experiences of local farmers, they can understand dried conditions of peat for using as fuel. After drying, they store the peat in gunny/plastic bags for year-round use. After several days of drying in the sunlight, the formed peat briquettes do not absorb moisture. To use these harvesting and processing steps, it is necessary to know whether the peat is feasible for the use as cooking fuel in rural areas of Bangladesh or if its frequent use poses environment and health hazards.

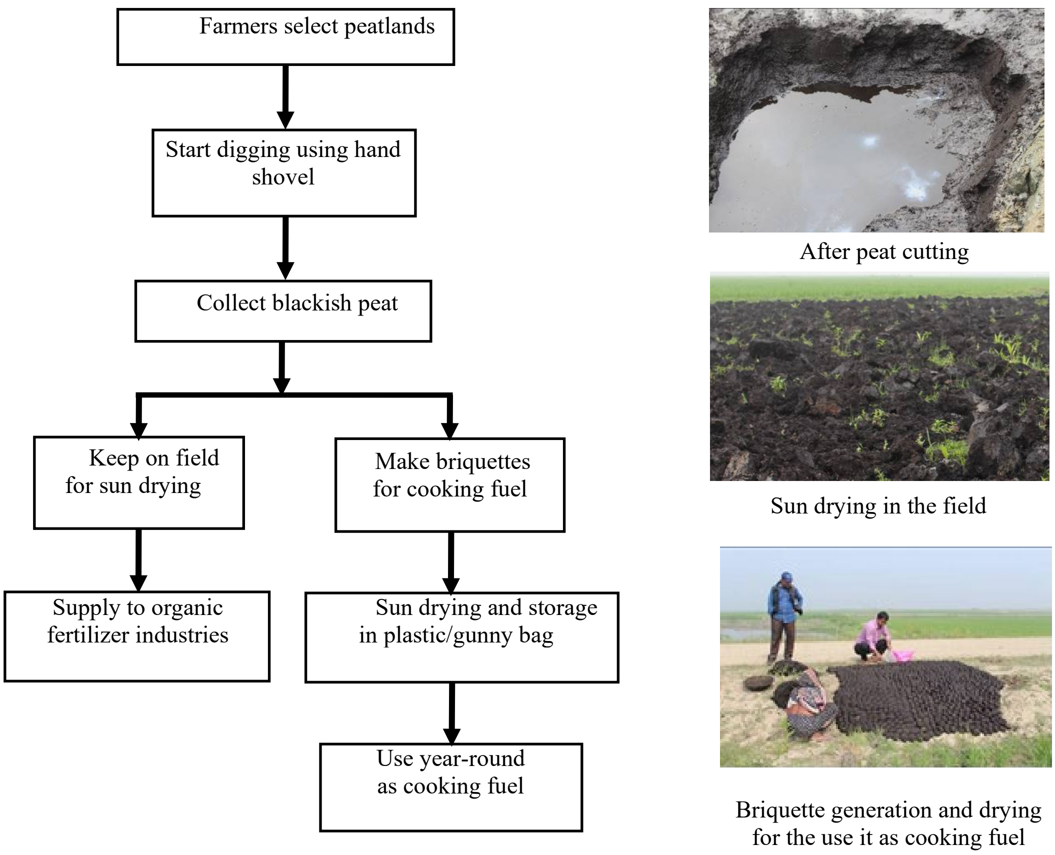


Figure 5 Flowchart of farm activities necessary to produce peat for the use as cooking fuel

2.4.2 Peat for fertilizers

Peat is widely used as fertilizer for vegetables and horticulture crops worldwide. There are several small peat-based businesses (agrofarms) in Bangladesh. They collect peat from *haor* or lowland areas. There is a supply chain between agrofarms and local farmers. Farmers supply peats to agrofarms with well dried. In agrofarms, they have crusher to crush raw peat samples. After making powder form of peat, agrofarms generally mix the powder of peat with other ingredients such as poultry excreta and cow manure. There is another supply chain between agrofarms and end user of peat as fertilizer. Aftersmall packaging (1 kg generally) of peat fertilizer, agrofarms use the supply chain for end users. The whole procedure has been mentioned in the flowchart in Figure 6. To obtain information regarding the production procedure of organic fertilizer, we visited an agrofarm in Mymensingh, Bangladesh, during this study. The physical and chemical properties of the peat collected from the study areas were analyzed to determine the potential of peat as organic fertilizer for the production of vegetables and horticulture crops in Bangladesh.

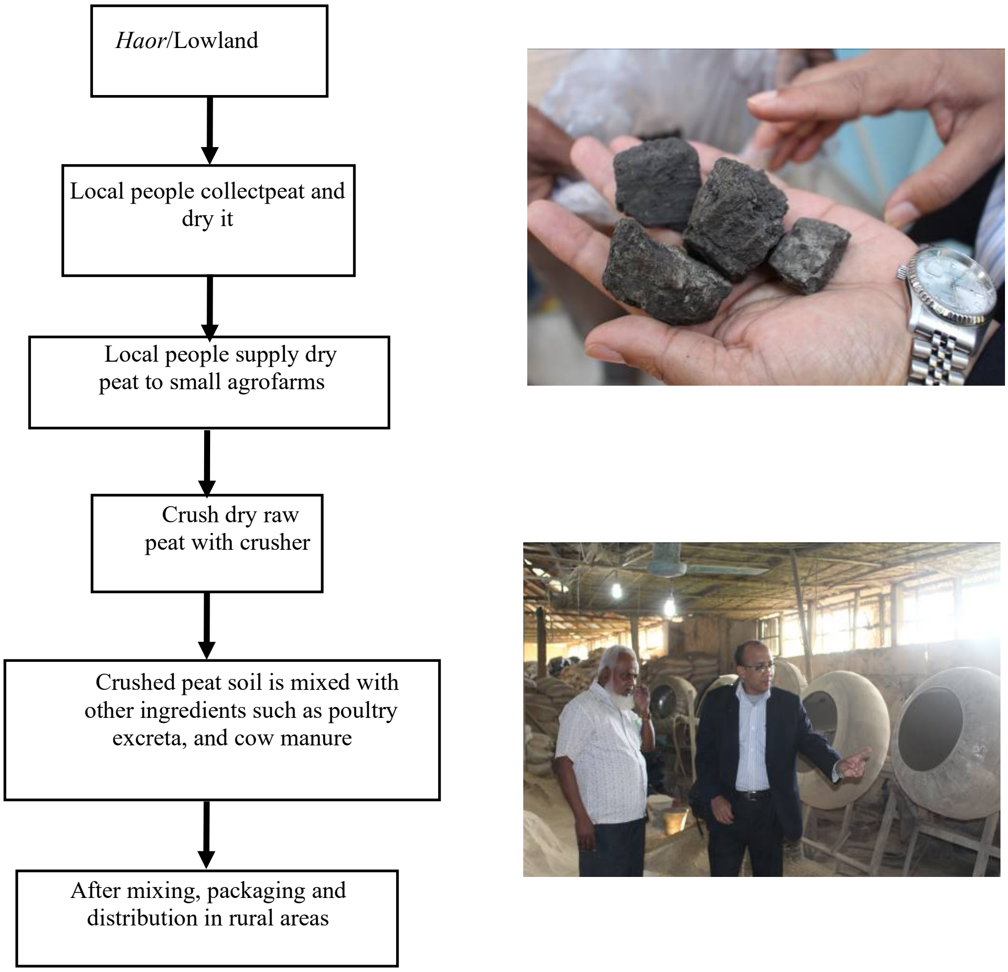


Figure 6 Flowchart and activities necessary to produce organic fertilizer in small industries

3 Results and discussion

3.1 Physical and chemical properties of peat

Physical and chemical characterization of peat is important for using it as fuel and fertilizer. The physical and chemicalproperties ofpeat generally differ depending on the land use or land management such as un-drained and drained forest, degraded land and managed agricultural land.In addition to these, several factors, such as organic material, minerals, depth, water, and aeration, influence the physical properties of peat. Based on the utilization of the peatland, these factors vary depending on the drainage and/or season. Peat lumps are lighter in weight than mineral soil when dried. Delayed draining, low-bearing capacity, irreversible property changes after drying, and deep flooding in the rainy season are the main limitations of peatlands (Masud et al., 2011). It is necessary to consider all above mentioned factors and conditions for appropriate management of peatlands. The physical properties of peat from two different locations are shown in Table 1. There are no significant differences in the dry matter, ash content, and organic carbon. The major component of peat is carbon. The total volatile carbon content is 66.6%–69.3%. The carbon content varies according to the annual wet and dry periods and decomposition level. The ash content of peat as shown in Table 1 indicates that the peat collected from *haor* areas are highly decomposed and has a high ash content.

Table 1 Physical properties of peat

Location	Dry matter (%)	Ash content (%)	Volatile Solid (Organic Carbon)	
			W.b. (%)	D.b. (%)
Mohanganj	23.30	8.20	12.2	69.3
Katiadi	21.47	7.17	14.3	66.6

Peats are generally considered to be partly decomposed biomass (vegetation).The chemical properties of peat are influenced by the vegetation, organic components available in the peat swamp, environment on the basis of weather conditions, and rate of decomposition depending on the anaerobic conditions in the deeper layers. The rate of decomposition of peat plays an important role in peat settlement. In this study, the pH, organic matter, N, P, K, and S contents of the peat were analyzed. The chemical properties of peat from two study locations are shown in Table 2.

Table 2 Chemical properties of peat. The listed values represent averages

Location	pH (0 ~7 acidic)	OrganicMatter (%)	N (%)	P (%)	K (%)	S (%)	Texture Class
Netrokona	5.42	11.41	0.58	0.038	1.55	0.462	Sandy loam
Katiadi	5.64	16.74	0.65	0.020	0.32	0.907	Sandy loam

The low pH may be due to the very high S accumulation of organic residues of peat. Peat soils are well known for their high sulfur contents. The high sulfur contents of peats are commonly associated with mineral soils, so-called potential acid sulfate soils. The presence of sulfur compounds in the organic materials can lead to strong acidification of the peat after drainage and reclamation (Andriesse, 1988). Higher nitrogen content in peat is released by the long-term decomposition of the organic residues of plants available in peatlands (Cao, 2019). The nitrogen content of peat soils is an important parameter for agriculture. The peat from the study areas has a moderate to good quality based on the physical and chemical properties.

3.2 Potential of peat as fuel

Peat has been used as an energy source for at least 2000 years. It is a useful alternative to firewood for cooking and has been used in many countries. The inorganic substances in peat deposits quantitatively and qualitatively vary and affect the ash content, which is a useful parameter when assessing the value of peat for fuel (Andriesse, 1988). The percentage of organic carbon in peat is the most valuable fuel source. The m.c. of processed peats, which varies, influences their combustion properties and calorific values. The average MC percentage of peat, rice husk briquettes, and cow dung is 11.3, 9.3, and 13.3, respectively.

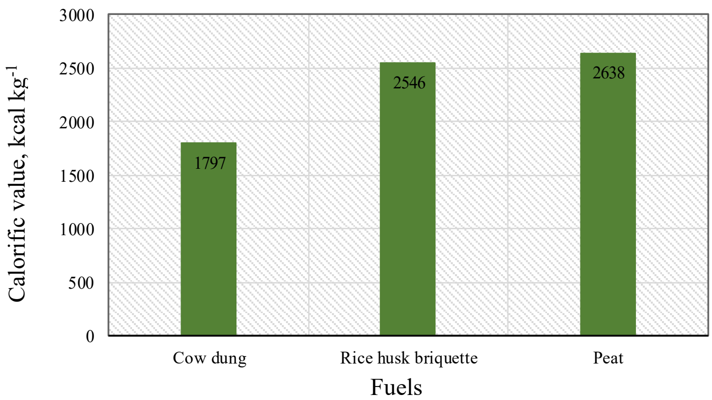


Figure 7 Calorific values of different fuels

Therefore, cow dung and rice husk briquettes are commonly used as cooking fuels in Bangladesh. All cow dung and peat samples were dried under open sunlight. The MC of rice husk briquettes was measured after collecting samples from the local market. It is very difficult to prepare different samples with the same MC. The calorific value of oven-dried peat is generally ~20 MJ kg^{-1} (Andriesse, 1988). In Khulna district of Bangladesh, the range of calorific value (Higher heating value) of peat was found 20.1~28.6 kJ kg^{-1} (Ahmed et al., 2019). It depends on the formation and decomposition structures of peat. The calorific value of rice husk is 3040 kcal kg^{-1} (Islam et al., 2014). For comparison, the calorific values measured on different fuels are given in

Figure 7. In this study, peat exhibits the maximum calorific value. There is no significant difference between peat and rice husk briquettes. Many households in *haor* areas use peat as a cooking fuel.

Several researchers mentioned that peat can be used for different purposes such as fuel for power production, cooking, domestic heating, brick fields, insulator in many industries, agricultural purposes, and raw material in horticulture (Masum et al., 2014; Andriesse, 1988). Based on available information and a field visit of the study areas, peat is used as cooking fuel only in limited areas of *haor* and low-lying zones in Bangladesh. The economic viability of peat as a fuel depends on the local conditions, including the availability of other fuels, labor, material costs, transportation distances, climatic conditions, and the possible scale of the operation (Andriesse, 1988). In addition, it is necessary to assess potential human health hazards and environmental degradation due to emissions from the combustion of peat and peat harvesting from land. Combustion of tropical peat generally emits CO and SO_2 (Kuwataetal., 2018). At the same time, the use of peat as a fuel for different purposes ensures the reduction of deforestation and thus conserves forests.

3.3 Potential of peat as fertilizer

Peat has often been used as both a humus source and fertilizer in the past, with the expectation of results similar to those obtained with animal manure. Although increased yields were often obtained and the physical conditions of soils were improved, peat did not act like animal manure, which in part is due to deficiencies in mineral nutrients (Allison, 1973). Based on the physical and chemical properties of peat, the major and minor elements are not adequately balanced for crop production. As a fertilizer, peat has become a mature technology in the world.In developed countries, the collection, processing and industrial production of peat have been done on the basis of mature scientific theory. Generally, technological process can be summarized as follows: crushing, screening, pulping, drying, packaging, and finally forming a peat nutrition bowl (Cao, 2019). In Bangladesh, after the collection of peat from *haors* and lowlands, some agrofarms mix the other ingredients with the peat to produce and supply a peat-based organic fertilizer packet to hilly areas for garden vegetables, potted plants, and horticulture crop production. Animal manure is mixed with peat in many cases to enrich the peat with mineral nutrients. Animal manure serves as a peat inoculant. Due to the decomposed fibers in the peat, roots of plants penetrate easily and an extensive root system can quickly develop.

3.4 Management of peatland

Peatlands and peat are used and managed for many different purposes worldwide. In Bangladesh, peatlands and peat are available in *haor* and lowland areas. These areas are characterized by different ecosystem scenarios. They remain fully flooded for at least six months in the wet season and are dry during the rest of the months. During the dry season, most of the *haor* areas are converted into agricultural land;some areas are used for the extraction of peat for the use as cooking fuel and fertilizer for the horticulture industry. These areas are flooded during the wet season and function as a shelter to hatch fishes and protect adult fishes that have high economic value. However, seasonal variation is common in terms of wildlife and floral diversity (BHWDB, 2017).

Peat has many uses, as indicated in the previous sections. The use in agriculture and as an alternative energy source is the most important applications. Peats, when properly managed, are considered to be the most productive soils. Depending on the m.c. of the peat, it is fired as cooking fuel, either with complete or incomplete combustion. In addition to CO_2, CO, CH_4, and a range of hydrocarbons are produced during incomplete combustion. These emissions pose significant health risks to households (Biancalani and Avagyan, 2014). Therefore, a detailed chain of activities, as shown in Figure 8, is needed in the future to obtain a complete scenario for *haor* and lowland areas in Bangladesh. These activities will be valuable to establish more effective approaches for the management of peatlands and the development, preservation, and restoration of peat areas in Bangladesh.

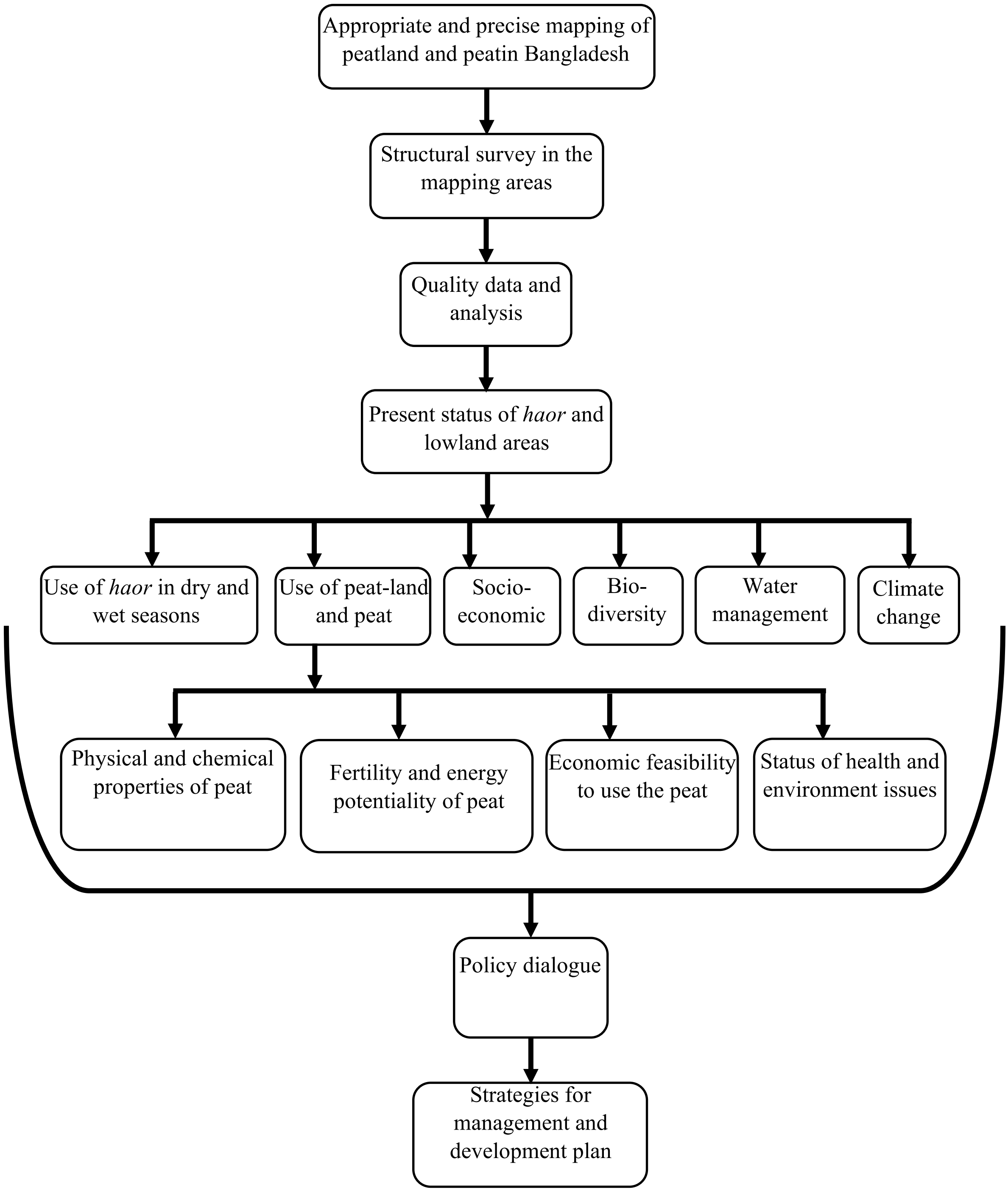


Figure 8 Approaches to determine strategies for the management and development of sustainable conservation and utilization of peatland and peat in *haor* and lowland areas in Bangladesh

4 Conclusions

Peat from the study areas has a moderate quality based on the physical and chemical properties. Some rural communities in the study areas use peat as cooking fuel and for the production of vegetable fertilizers for agrofarms. The Government of Bangladesh is making efforts to identify cheaper and more reliable fuels as alternatives to coal. Peat is still not competitive due to the availability of cheap oil, coal, and natural gas in Bangladesh. Peat is used only in some *haors* as cooking fuel, on a minor scale. Before the wide application of peat for different purposes, detailed investigations need to be carried out to determine the feasibility of its use with respect to socioeconomic, landslide/subsidence, and health and environment aspects. The calorific value of peat is higher than that of cooking fuels commonly used in Bangladesh such as cow dung and rice husk briquettes. The heating potential of peat is therefore satisfactory for the use as fuel. Future analyses of the conversion of peat to combustible gases will provide information about the user- and environment-friendly status of peat as fuel.

Acknowledgement

The authors would like to acknowledge the *Tropical Peatland Society Project*, RIHN, Kyoto, Japan, for providing financial support to conduct the research work in Bangladesh.

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