AVAILABILITY AND UTILIZATION PATTERN OF AGRICULTURAL WASTE AT THE HOUSEHOLD LEVEL IN SELECTED AREAS OF BANGLADESH

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Abstract

Using organic fertilisers is one of the best solutions for improving the organic matter levels and turnover in the soil. It may also be possible to substitute a portion of chemical fertilizers with products that are acceptable and available to the farmers. The types, availability and use of household agricultural waste in Bangladesh farms are not well quantified. Therefore, a study was conducted to find out the types of waste materials available for recycling and their usage patterns at the household level. A total of 300 households were purposively selected from Barguna, Khulna, Mymensingh, Rajshahi and Thakurgaon districts for this study. The total amount of agricultural waste produced at the household level was 822 kg per month. Cowdung contributed about 65% of the total waste followed by animal feed refusal waste (11%), garbage (7%) and kitchen waste (6%). The usage patterns of cow dung varied throughout the year depending on the season or weather conditions. Most farmers dumped the non-utilized cow dung and wastes in a heap or pit and used them in the dry season as organic fertilizer. The next potential use of dry cow dung was as fuel. The other agricultural wastes like ash, cattle feed waste, kitchen waste, household garbage, rice husk, etc. were used for composting to some extent. A small portion of farmers throw some parts of household waste into open ditches or surrounding areas. The survey also reveals that a household can reduce the chemical fertilizer cost by a total Tk. 1463 per month by using compost prepared at the household level. Most farmers were not aware of the proper use of household waste and did not follow the scientific methods for compost preparation. There were ample opportunities for vermicomposting and its potential market in the study areas. Department of Agriculture Extension (DAE) should provide more focus on improving compost management through its agricultural innovation program and may increase its demonstration at the community level.

Keywords: Agricultural waste utilization/management, cow dung, manure, compost, organic fertilizer

1. INTRODUCTION

Soil degradation due to organic matter depletion remains a concern for crop production in many places globally (Zahid et al., 201l). An organic matter content more than 3.5% is proposed to maintain soil fertility and crop productivity (Johnston et al., 2009). The overall organic matter content is usually low in the agriculturally important soils in Bangladesh (Moslehuddin and Laizoo,

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1997). Most soils of Bangladesh have an organic matter content of less than 1.7% and in some areas, soils have less than 1% organic matter (Hossen et al., 2015; Islam, 2006). Hence, the addition of compost to the soil can improve the present status of organic matter content in the soil. The most commonly used organic matter is the farmyard manure which is not scientifically prepared thus there are wide gaps between the requirement and availability. The recycling of organic wastes through composting can meet this increased demand for compost.

The organic fraction of bio-resources in rural areas represents a valuable resource which could be recycled and transformed into nutrient-rich fertilizer or soil conditioner (Bernstad et al., 2016; Calabi-Floody et al., 2017). Biological degradation during composting and vermicomposting are strategies to transform these organic wastes into organic amendments (Barthod et al., 2018).

According to the United States Environmental Protection Agency (USEPA), agricultural waste is the byproducts generated by the rearing of animals, and the production and harvest of crops or trees. Animal waste, a large component of agricultural waste, includes (i.e. feed waste, bedding and litter, and feedlot and paddock) runoff from livestock, dairy, and other agricultural practices. Farm households in their daily activities are major generators of agricultural wastes, in the form of manure, crop residues or mixed solid wastes. Composting can play an important role in farm households by reducing environmental threats linked to improper organic waste management and improving soil fertility, which will have immediate impact upon crop productivity (Mohee, 2007). Farm households in the rural areas generally gather agricultural waste from different agricultural activities and put them together in a hole for a certain period and use it later as compost in crop field. They hardly sale decomposed agricultural waste for earning cash. In most cases, farmers do not follow scientific methods for composting agricultural as well as solid waste that creates many environmental and health hazards (Alam and Ahmade, 2013). Data and information regarding agricultural waste availability, decomposing and utilization at household as well as community level are scarce in Bangladesh.

We conducted this study under the Australian Centre for International Agricultural Research (ACIAR) and Krishi Gobeshona Foundation (KGF) funded project "Nutrient Management for Diversified Cropping in Bangladesh (NUMAN)" to study the farm level bio-resource recycling potential from agricultural waste materials which may help rural communities and farmers to establish and operate composting facilities and the proper use of compost. Also, it may be a useful resource for institutions and researchers involved in organic waste management, and NGOs and Community Based Organizations from the public and private sectors.

1.1 Objectives of the Study

1. To determine the amounts and types of agricultural waste materials available for recycling at the farm household level;
2. To know the utilization pattern of agricultural waste materials at the farm household level; and
3. To recommend some policy guidelines for agricultural waste materials recycling.

2. MATERIALS AND METHODS

2.1 Sources and Method of Data Collection

Primary data were collected from selected farm households with the aid of a pre-tested interview schedule. The personnel of the NUMAN Project in the respective project hubs, Conservation Agriculture Service Providers Association (CASPA) and DAE personnel assisted researchers and enumerators in collecting primary data. Secondary data were collected from Fertilizer Recommendation Guide-2018 and the annual report of Soil Science Division of BARI.

2.2 Sampling Procedure and Sample Size

Since the NUMAN project has been implementing in six Upazilas of five districts (Durgapur and Godagari Upazilas of Rajshahi, Sadar Upazila of Thakurgaon, Sadar Upazila of Mymensingh, Dacope Upazila of Khulna and Amtali Upazila of Barguna), hence two agricultural blocks (AB) from each Upazila were selected for farm household survey. From each block 25 households (HH) were purposively identified those were engaged for crop farming and had at least 2 cattle. Thus, the total of 300 households were interviewed for this study.

2.3 Agricultural Waste Materials

Cowdung, excreted from goat, chicken, duck and pigeon, kitchen scraps, fruit and vegetable peels, refusal of feed waste, household garbage, HH level crop residues, rice/wheat husk, kitchen and bush ashes.

2.4 Data Management and Analysis

The collected data were scrutinized, coded, cleaned and entered into MS Excel first and then exported to the SPSS. All the collected data were analyzed in accordance with the study objectives. Mostly, descriptive statistics were used for analysing the collected data and it was analysed using SPSS software. In addition, the following empirical multiple linear regression model was used to identify factors affecting the amount of agricultural waste at the household level.

$$Y = a_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + \text{-----------------------} \; Ui$$

Where, Y= Amount of agricultural waste at household level (kg/month)

a_0 = Constant term (Y-intercept)
X_1 = No. of cattle per household
X_2 = No. of goat/sheep per household
X_3 = No. of poultry per household
X_4 = Cultivated land (decimal/HH)
X_5 = No. of family member per household
b_1, b_2, b_3, -----b_5 is the slope coefficients of each explanatory variable to be estimated
Ui = the model’s error term

3. RESULTS AND DISCUSSION

3.1 Family Size

The quantity of agricultural waste materials of a household is likely to be influenced by the family size as more family member means more kitchen waste. The average family size of the respondent farmers was 5.39/HH, this was higher than the national average of 4.06/HH (HIES, 2016). Among the study areas, the largest family size was found in Mymensingh district (5.92 /HH) and smallest in Barguna district (4.88 /HH). The number of adult male and female family members were more or less similar in the study areas (Table 1).

Table 1. Family size (No./HH) of the respondent farmers in the study areas

Category	Barguna *(n=50)*	Khulna *(n=50)*	Mymensingh *(n=50)*	Rajshahi *(n=100)*	Thakurgaon *(n=50)*	All Area *(n=300)*
Adult male	1.52	1.86	1.98	2.42	1.66	1.98
Adult female	1.52	1.70	1.94	2.11	1.62	1.83
Child	1.84	1.42	2.00	1.28	1.66	1.58
All category	4.88	4.98	5.92	5.81	4.94	5.39

3.2 Cultivated Area

Land is the most important asset for farm households because farm families mostly depend on the land. Nevertheless, the quantity of agricultural waste of in household also depends on the cultivated area. The cultivated area includes the area of own cultivated land plus rented-in land minus rented-out land. As shown in Table 2, the average cultivated land of all respondent farmers was 183 decimals (0.74 ha) per HH with minimum and maximum of 48 decimals and 644 decimals per HH. Across the study areas, the largest cultivated land size was observed in Mymensingh district (278 decimal/HH) followed by those in Rajshahi (219 decimal/HH) and Thakurgaon districts (155 decimal/HH), Khulna (141 decimal/HH), and the smallest (88 decimal/HH) was in Barguna district.

Table 2. Average cultivated area (decimal/HH) of the respondent farmers

Cultivated area	Barguna *(n=50)*	Khulna *(n=50)*	Mymensingh *(n=50)*	Rajshahi *(n=100)*	Thakurgaon *(n=50)*	All Area *(n=300)*
Minimum	45	30	60	66	20	48
Maximum	264	500	1000	800	500	644
Mean	88	141	278	219	155	183

3.3 Cultivated Area under Different Crops

The respondent farmers in the study areas cultivate different types of crops throughout the year. The cultivated crops included cereals, jute, tubers, vegetables, pulses, oilseeds and spices. The highest diversification of crops was found in Rajshahi district (17 types) followed by Barguna (13 types), Mymensingh (12 types) and the lowest in Khulna district (5 types). In all areas, the average highest amount of land was devoted to cultivate *T. Aman* rice (152.5 decimal/HH) that was followed by mustard (108.4 decimal/HH), *Boro* rice (108.2 decimal/HH), maize (82.2 decimal/HH), tomato (69.7 decimal/HH) and lentil (64.1 decimal/HH). The cultivated lands devoted to different crops shows diverse picture among study areas. After cultivating rice crops, the highest amount of land was used for vegetables cultivation in Barguna and Khulna districts. Again, the highest amount of lands was planted to mustard, lentil, and maize cultivation in Mymensingh, Rajshahi, and Thakurgaon district, respectively (Table 3).

3.4 Livestock Holdings

The average holdings of the adult cattle (≥ 1year) and calves (≤1year) were 2.97 and 1.06 per household in the study areas, respectively. In the case of small ruminants (goat/sheep) and poultry, the average holdings were 2.35 and 16.6 per household, respectively. Rajshahi farmers owned the highest number of cattle (3.38 per household) which was followed by the farmers of Thakurgaon (3.24 per household and Khulna (2.98 per household district. Although the average holding of cattle was lowest in Barguna district, the average holdings of the small ruminant (goat/sheep) and poultry were highest in this district (Table 4).

Table 3. Total cultivated area (decimal) under different crops grown in the study farms

Cultivated crops	Barguna		Khulna		Mymensingh		Rajshahi		Thakurgaon		All areas	
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
T. Aman	50	83.6	49	128.2	50	257.7	95	153.3	42	135.7	286	152.5
Boro	--	--	22	77.1	10	129.1	66	107.3	24	130.2	122	108.2
Maize	7	12.0	--	--	--	--	5	34.4	37	102.0	49	82.2
Wheat	8	16.5	--	--	1	50.0	20	49.0	15	30.6	44	36.8
Jute	--	--	5	52.0	1	35.0	5	31.6	3	30.0	14	38.8
Potato	12	9.3	--	--	4	28.0	14	24.7	3	36.7	33	20.6
Sweet potato	15	19.2	--	--	--	--	--	--	--	--	15	19.2
Tomato	--	--	--	--	9	70.1	1	66.0	--	--	10	69.7
Vegetable	2	36.0	12	60.0	9	52.3	28	25.8	1	25.0	52	38.6
Lentil	4	4.3	--	--	1	15.0	45	70.6	--	--	50	64.1
Mungbean	33	18.6	--	--	--	--	1	17.0	--	--	34	18.6
Chickpea	--	--	--	--	--	--	11	57.1	--	--	11	57.1
Black gram	4	9.8	--	--	1	100.0	5	79.4	--	--	10	53.6
Mustard	--	--	5	52.0	28	191.1	33	46.9	--	--	66	108.4
Sunflower	32	15.6	--	--	--	--	--	--	--	--	32	15.6
Groundnut	50	14.4	--	--	--	--	--	--	1	25.0	51	14.6
Onion	12	14.0	--	--	6	31.7	35	24.5	5	33.0	58	23.8
Chili	31	13.7	--	--	12	59.8	11	16.0	13	19.4	67	23.5
Garlic	--	--	--	--	--	--	4	4.5	--	--	4	4.5
Betel leaf	--	--	--	--	--	--	22	28.0	--	--	22	28.0

Table 4. Number of livestock owned by sample farmers in the study areas

Livestock type	Barguna *(n=50)*	Khulna *(n=50)*	Mymensingh *(n=50)*	Rajshahi *(n=100)*	Thakurgaon *(n=50)*	All Area *(n=300)*
Cattle (≥ 1year)	2.42	2.98	2.44	3.38	3.24	2.97
Calf (≤1year)	1.90	0.84	1.06	0.84	0.86	1.06
Goat/sheep	2.60	2.16	1.20	2.50	3.12	2.35
Chicken	44.08	10.16	12.38	12.59	7.82	16.6

3.5 Duration of Cattle Kept at Homestead

The amount of agricultural waste materials (i.e. dung, feed and fodder refusals) available at the household level is mostly dependent on the duration of cattle penning around the house. Results show that respondent farmers kept cattle in the house for 19.5-19.9 hours per day from mid-June to mid-September and for 17.6-17.7 hours per day during the month from mid-February to mid-April (Table 5). Among the study areas, cattle were kept for the longest period (21.5 hours/day) in Rajshahi district followed by Khulna (19.0 hours/day) and Mymensingh district (18.9 hours/day) and the lowest in Barguna district.

3.6 Availability of Agricultural Waste

Seven types of agricultural wastes are being produced or available at the farm household level (Table 6). The average amount of waste produced at the household level was 822 kg per month. The highest amount of agricultural waste produced was in Thakurgaon district (980 kg/month) followed by Rajshahi (875 kg/month) and Barguna district (772 kg/month). However, cow dung contributed the highest share (65%) to the total waste followed by cattle feed waste (11%) and household garbage (7%) and kitchen waste (Fig 1). Among the study areas, the highest quantity of cowdung was found in Rajshahi district (590 kg/month) due to holding higher average number of cattle (see Table 4) and their longer staying period in home (see Table 5).

Table 5. Average duration of cattle penning around the house in the study areas

Period of time	Staying duration (hour/day)					
	Barguna *(n=50)*	Khulna *(n=50)*	Mymensingh *(n=50)*	Rajshahi *(n=100)*	Thakurgaon *(n=50)*	All Area *(n=300)*
Mid-April to Mid-May	12.26	19.52	18.30	20.53	16.06	17.9
Mid May to Mid-June	15.80	19.52	18.14	20.59	15.94	18.4
Mid-June to Mid-July	19.24	19.74	18.86	21.19	16.86	19.5
Mid-July to Mid-August	20.06	19.74	19.06	21.61	16.42	19.8
Mid-August to Mid-September	19.96	19.84	19.60	21.66	16.46	19.9
Mid-September to Mid-October	17.08	19.78	19.14	21.84	15.72	19.2
Mid-October to Mid-November	14.52	19.46	18.82	22.51	16.46	19.0
Mid-November to Mid-December	12.00	18.44	18.64	22.40	15.98	18.3
Mid-December to Mid-January	12.00	18.20	19.14	22.33	21.20	19.2
Mid-January to Mid-February	12.00	17.88	19.70	21.92	21.20	19.1
Mid-February to Mid-March	12.00	17.86	19.04	20.84	15.72	17.7
Mid-March to Mid-April	12.00	17.82	18.88	20.66	15.40	17.6
Average	**14.9**	**19.0**	**18.9**	**21.5**	**17.0**	**18.8**

Table 6. Monthly quantity (kg) of agricultural waste produced at household level

Types of agricultural waste	Barguna *(n=50)*	Khulna *(n=50)*	Mymensingh *(n=50)*	Rajshahi *(n=100)*	Thakurgaon *(n=50)*	All Area *(n=300)*	Amount (kg/unit)
1. Cowdung	403.2	533.4	465.0	590.1	613.8	532.6	132.2
2. Goat & chicken manure	44.3	8.6	13.4	23.4	33.1	24.4	1.3
3. Kitchen waste	65.4	51.4	33.4	55.3	37.8	49.8	--
4. Cattle feed waste	105.6	92.4	76.8	89.1	104.7	93.0	23.1
5. Household garbage	52.8	25.5	55.9	45.8	97.2	53.8	--
6. Rice/wheat husk	15.8	14.5	13.6	17.6	32.0	18.5	9.5
7. Kitchen & bush ash	84.5	22.2	24.4	53.2	61.3	49.8	0
All wastes	**771.6**	**748.0**	**682.5**	**874.5**	**979.9**	**821.9**	**--**

Note: Unit means cowdung per cattle, manure per goat or chicken, feed waste per cattle, rice/wheat husk per acre

The average amount of excreta produced from small ruminants (goat/sheep) was estimated at 24.4 kg (3.0% of the total waste) per month. The amount of excreta was highest in Barguna district and the lowest in Khulna district. The average amounts of cattle feed waste, kitchen waste, and household garbage were estimated at 93 kg (11.3%), 49.8 kg (6.1%), and 53.8 kg (6.5%) per month, respectively.

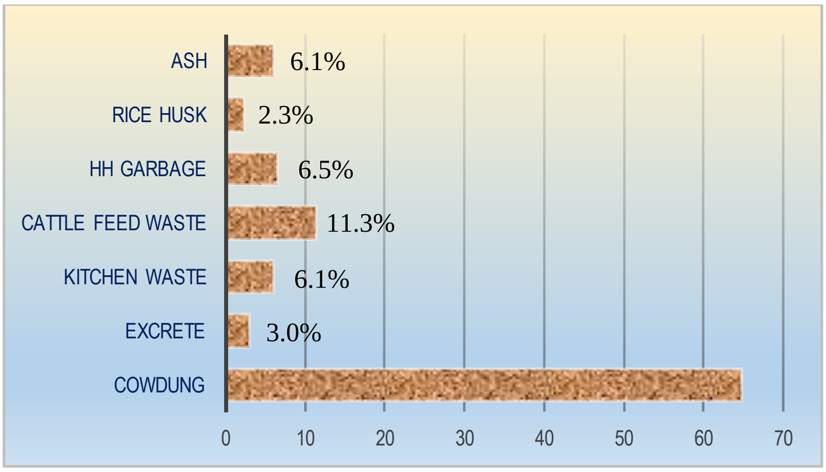

Figure 1. Percent share of agricultural waste at HH level, averaged across 5 districts

3.7 Factors of Production of Waste at Household Level

A functional analysis was applied to identify the factors affecting waste production at farm household level and the results of this analysis have been showed in Table 7. The number of holdings of cattle & small ruminant (goat/sheep), total area of cultivated land, and family size were found significant factors that influence the amount of waste production at household level. As for example, the coefficient of cattle holding is 114.49 and significant at 1% level implies that an increase of cattle holding by one unit, keeping other factors constant, the probability of household waste production would increase by 114.49 kg/month in the aggregate situation. Similarly, the coefficient of family size is 25.72 and significant at 5% level indicating that an increase of family size by one unit, keeping other factors constant, the probability of household waste production would increase by 25.72 kg/month in the aggregate situation. The coefficient of multiple determination (R^2) was 0.71 meaning that 71% of the variation in farm household level waste production was explained by the variables included in the model.

Table 7. Factors affecting the quantity of agricultural waste at household level

Variable	Coefficient	Std. Err	t-value	p>|t|
Constant	351.90***	30.65	11.48	0.000
Cattle holding (No./HH)	114.49***	4.72	24.24	0.000
Goat/sheep holding (No./HH)	9.22*	4.99	1.85	0.065
Poultry holding (No./HH)	0.33	0.84	0.40	0.692
Cultivated land (decimal/HH)	0.21**	0.09	2.26	0.025
Family size (No./HH)	25.72**	10.80	2.38	0.018
F-value	141.35***			0.000
R^2	0.706			
Adjusted R^2	0.701			
N	299			

Note: Dependent variable = Amount of agricultural waste (kg/month)
'***' '**' and '*' represent 1%, 5%, and 10% level of significant

3.8 Use of Cowdung at Household Level

Cowdung is mainly used as fertilizer, household fuel (Figs-1, -2 &-3) and for compost production in the study areas. Few farmers also use it as fish feed (Table 8). Dried cowdung is an excellent fuel in most of the study areas. Respondent farmers in the study areas collected and dried cow dung mostly in the winter for fuel, sometimes after being mixed with straw. Pieces of dry dung are lit to provide heat and a flame for cooking. Most respondent farmers in the study areas used cow dung for preparing compost that was used as a fertilizer (Figs-4, -5, & -6). It was observed that most of the farmers were not aware of the utilization of cow dung properly and did not follow the scientific methods for compost preparation. Cowdung produced in the rainy season (mid-April to mid-August) is generally thrown in an open pit or kept in a heap in some study areas (Table 8). It might happen as they have less knowledge of the benefits of cow dung composting and its importance in crop farming. Again, this cowdung can be used for preparing vermicomposting and it has potential market in some of the study areas. Vermicomposting needs technical know-how and financial assistance which are absent in most the study areas.

Fig-1. Cowdung cakes drying on the tree

Fig-2. Drying cowdung stick for fuel

Fig-3. Mound of dried cowdung fuel

Fig-4. Raw cowdung manure pile

Fig-5. Cowdung manure rotted compost

Fig-6. Cowdung manure rotted compost

Table 8. Annual cowdung use in the study areas

Period of time	Dried for fuel		Prepare compost		Storing in pit/heap		Used as fish feed	
	% response	% use	% response	% use	% response	% use	% response	% use
Mid-April to mid-May	23.8	20.6	78.6	78.4	21.6	21.0	0	0
Mid May to mid-June	23.0	18.4	79.4	80.2	21.2	21.4	0	0
Mid-June to mid-July	11.4	8.0	87.2	89.8	22.2	21.8	0.4	0.4
Mid-July to mid-August	9.8	6.2	87.0	91.0	21.8	22.2	1	0.6
Mid-August to mid-September	18.4	16.8	80.0	81.2	12.0	11.6	0.4	0.4
Mid-September to mid-October	37.4	33.4	62.8	65.2	2.2	1.0	0.4	0.4
Mid-October to mid-November	56.0	53.6	46.2	45.6	0.4	0.6	0.2	0.2
Mid-Nov. to mid-December	64.2	62.2	38.2	37.2	0.8	0.6	0	0
Mid-December to Mid-January	66.0	62.4	36.0	37.2	0.4	0.4	0	0
Mid-January to mid-February	66.4	63.8	36.0	35.6	0.8	0.6	0	0
Mid-February to mid-March	67.4	65.0	35.4	34.6	0.4	0.4	0	0
Mid-March to mid-April	66.8	63.8	35.2	35.8	0.8	0.4	0	0

In Khulna district, 82-88% respondent farmers used more than 80% of the total cowdung for compost preparation during the period from mid-April to mid-October and the rest amount was used as cooking fuel (Appendix Table 2). Again, 80-86% respondent farmers in Mymensingh district and 70-86% respondents in Rajshahi district used 74-90% of the total cowdung for compost preparation during the period from mid-June to mid-October (Appendix Tables 3 &

4). The highest proportion of cow dung (90-97%) was reported to be used as compost throughout the year in the Thakurgaon district (Appendix Table 5). Few farmers in Rajshahi district used cow dung as fish feed. However, some farmers from Mymensingh and Rajshahi districts stored a portion of cow dung in open pit.

3.9 Use of Goat and Chicken Manure

Goats produce comparatively neat pelletized droppings that don't typically attract insects or burn plants as does manure from cows or horses. It is virtually odourless and is beneficial for the soil (www.gardeningknowhow.com/composting/manures/goat-manure-fertilizer.htm). The most common use of goat manure is as an organic fertilizer. It can help farmers produce healthier plants and crop yields. Chicken manure has the highest amount of nitrogen, potassium, and phosphorus among all animal manures (Martin and Gershuny, 1992; Barrett, 2008). It is used also as an organic fertilizer, especially for soil low in nitrogen (Mick, 2015). Chicken manure can be used to create homemade plant fertilizer (Patricia and Cheryl, 2013). A study conducted in the Philippines showed that the use of chicken manure as a fertilizer in milkfish production in brackish water ponds performed the best after cow manure (Garcia et al., 2007).

More than half of the respondent farmers in the study areas used goat and chicken manure for compost preparation. The highest percentage of farmers in the Rajshahi district used these manures for compost preparation and the lowest in the Barguna district. Respondent farmers do not prepare compost from separately the manures collected from goats and chickens. Usually, they collect it and mix it together in the cow dung heap. On average, 35% of farmers discard goat and chicken manure possibly due to small quantities produced or putting less importance on it. The highest percentage of Barguna farmers (86%) were reported to discard goat and chicken manures followed by Mymensingh (66%) district (Table 9).

Table 9. Percent response on the use of goat and chicken manure in the study areas

Type of usage	Barguna *(n=50)*	Khulna *(n=50)*	Mymensingh *(n=50)*	Rajshahi *(n=100)*	Thakurgaon *(n=50)*	All Area *(n=300)*
Prepare compost	6	70	24	77	68	54
Keep with cowdung	8	14	10	12	12	11
Discarded	86	16	66	11	20	35

3.10 Use of Household Waste Materials

Household waste also known as domestic waste, is disposable materials generated by households. This waste comprised of non-hazardous waste and hazardous waste. Non-hazardous waste includes food scraps, unused cattle feed and fodder, garbage, rice husk, ash, paper, bottles, metallic & non-metallic items, etc. which can be recycled or composted. Whereas, hazardous waste includes batteries and household cleaners. The present study discusses only those household waste that can be used for composting and used as fertilizer.

Kitchen waste**:** Kitchen waste which includes vegetable peelings, fruit waste (apple pumice, banana peels etc.), cheese rind, cooked and uncooked food that are left over from cooking (Fig-7). The compost prepared from kitchen waste (Fig-8) contains valuable organic matter and nutrients. About 44% of the respondent farmers in the study areas ignored the importance of kitchen waste and discard them. All the respondent farmers of Barguna district discard kitchen waste followed by 78% respondents of Mymensingh district. On an average, 36% farmers used kitchen waste as cattle feed and 16% used it for compost preparation. Only 4% of farmers added kitchen waste to the cowdung heap (Table 10).

Fig-7. Household kitchen waste

Source: www.supermarketperimeter.com

Fig-8. Compost from kitchen waste

Source: www.ndtv.com/photos/news/

Table 10. Percent response on the use of household kitchen waste in the study areas

Type of usage	Barguna *(n=50)*	Khulna *(n=50)*	Mymensingh *(n=50)*	Rajshahi *(n=100)*	Thakurgaon *(n=50)*	All Area *(n=300)*
Discarded	100	20	78	24	16	44
Use as feed	--	70	14	38	56	36
Prepare compost	--	10	--	32	22	16
Mixed with cowdung	--	--	8	6	6	4

Cattle feed and fodder waste: The amount of uneaten feed or fodder is classified as *refusal* and *wastage*. Refusal is the amount of feed and fodder that remains in the feed and fodder basket, on pasture and on bare ground, and does not get consumed by cows after a certain period of time following the feed-out. The refusal may or may not be eaten at a later stage. Wastage is the amount of feeds and fodder that are contaminated with urine or feces and soil or spread out around the feed-out area and will not be eaten by cows at a later stage (Fig-9). The amount of feed and fodder wastage depends on many factors such as feeding methods, intervals between feedings, amount fed at a time, climatic conditions, number of cattle being fed, access of cattle to feed and fodder, competition for the feed and fodder quality (DAGF, 2009). Overall 43% of respondent farmers in the study areas discard the feed and fodder waste, 37% used it as fuel, and 20% used it for preparing compost. The results further reveal that 86% of respondent farmers from Mymensingh district discard cattle feed and fodder waste, 55% farmers from Rajshahi district used it as fuel, and 36% farmers from Thakurgaon district used it for preparing compost (Table 11).

Fig-9. Feeding cattle and feed/fodder waste at household level

Table 11. Percent response on the use of cattle feed and fodder waste in the study areas

Type of usage	Barguna *(n=50)*	Khulna *(n=50)*	Mymensingh *(n=50)*	Rajshahi *(n=100)*	Thakurgaon *(n=50)*	All Area *(n=300)*
Discarded	60	66	86	18	10	43
Use as fuel	40	12	8	55	54	37
Prepare compost	--	22	6	27	36	20

Use of household garbage: Varying quantities and types of garbage are generated at household levels in the study areas. Household garbage includes paper, cardboard, paper cartoon, plastic, polybags, metals, glass, electronic waste, plaster from coatings of walls, wood, hazardous waste, food waste, crop residues, dust, etc. (Fig-10). Most of the respondent farmers throw this garbage into open spaces adjacent to the homestead in open ditches in the surrounding areas. Only 23% and 16% of the respondent farmers used some of the garbage as fuel and green garbage for preparing compost, respectively. Table 12 reveals that 100% of respondents from Barguna district discard household garbage, 48% farmers from Rajshahi district used it as fuel, and 26% farmers from Khulna district used it for preparing compost.

Fig-10. Household garbage littered on the road side

Table 12. Percent response on the use of household garbage in the study areas

Type of usage	Barguna *(n=50)*	Khulna *(n=50)*	Mymensingh *(n=50)*	Rajshahi *(n=100)*	Thakurgaon *(n=50)*	All Area *(n=300)*
Discarded	100	70	86	29	54	61
Use as fuel	--	4	8	48	28	23
Prepare compost	--	26	6	23	18	16

Use of rice husk: Rice husk are the hard protective coverings of rice grains that are separated from the grains during the process of milling. It is a cellulose-based material but contains 20% silica in amorphous form (Hu et al., 2008; Mansaray and Ghaly, 1998; Nair et al., 2008; Ndazi et al., 2007). About half of the respondent farmers in the study areas used rice husk as cooking fuel, especially for parboiling rice. Due to its nutritive value, about 39% farmers used it as cattle feed. Only 11% farmers used rich husk as an ingredient for compost preparation by mixing with cowdung. Detailed district-wise results are shown in Table 13.

Table 13. Percent response on the use of rice husk in the study areas

Type of usage	Barguna *(n=50)*	Khulna *(n=50)*	Mymensingh *(n=50)*	Rajshahi *(n=100)*	Thakurgaon *(n=50)*	All Area *(n=300)*
Use as fuel	44	56	52	50	50	50
Use as cattle feed	50	30	36	38	40	39
Prepare compost	6	14	12	12	10	11

Use of ash: Ash is the powdered residue left after the burning wood, bamboo, dry leaves, paper, dry dung, jute stick, paddy husk, dry cowdung, etc. It serves as a source of potassium and calcium carbonate, the latter acting as a liming agent to neutralize acidic soils (Lerner, 2000). In many cases, ash can be used as an organic/ inorganic fertilizer to enrich soil nutrition. The combined use of lime, cowdung manure and kitchen ash increased the yield and yield components of faba bean in Ethiopia (Asrat et al., 2020). Ash effectively reduced the damage of insects to maize grains (Golob and Hanks, 1990). Many farmers traditionally use ash to protect stored commodities from bruchid damage during storage (Golob et al., 2002).

In the study areas, about 47% respondent farmers stated that they had little use of ash and in most cases they throw it out. The highest percentage of farmers' form Barguna and Mymensingh district (83%) and the lowest from Rajshahi district (13%) have thrown out ash. Nearly 33% of farmers used ash for preparing compost and 10% of farmers applied it in the crop fields. Rajshahi and Thakurgaon farmers used ash in much higher proportions for preparing compost than the farmers of other study areas. Rajshahi farmers also applied more ash in the crop fields compared to the farmers of other study areas. A minor portion of farmers use ash as litter in poultry farms (Table 14).

Table 14. Percent response on the use of kitchen/bush ash in the study areas

Type of usage	Barguna *(n=50)*	Khulna *(n=50)*	Mymensingh *(n=50)*	Rajshahi *(n=100)*	Thakurgaon *(n=50)*	All Area *(n=300)*
Discarded	83	65	83	13	25	47
Prepare compost	--	24	--	59	54	33
Apply in the field	12	--	9	15	7	10
Kept with dung	5	--	8	9	14	8
Use as litter	--	11	--	5	--	4

3.11 Economics of Compost Use in Crop Production

Plants generally get only one (sometimes more) nutrient from individual chemical fertilizer products, but organic fertilizer supplies most of the essential nutrients to the plant. For instance, urea fertilizer supplies only N, whereas decomposed cow dung (about 20% moisture) supplies almost all the essential plant nutrients including N. Hence, Integrated Plant Nutrition System (IPNS) suggests to use of both chemical and organic fertilizers aiming to reduce the use of chemical fertilizers for crop production and improve the soil health (FRG, 2018).

Farmers can reduce the use of chemical fertilizers as well as save the cost of crop cultivation by using compost from agricultural household waste in crop farming. For example, if the recommended dose of inorganic fertilizer is 120 kg N/ha with 5 t/ha cow dung, 5 tons of cow dung supplies 25 kg N/ha. Hence, (120-25) kg = 95 kg/ha N will be required from inorganic fertilizer. Therefore, the cost of 25 kg N equivalent to 54.34 kg of urea (46% N) is (Tk. 16 × 54.34 kg) = Tk. 870/ha can be saved. Like N, the other nutrients can be reduced by using organic fertilizer which can save money from less inorganic fertilizer use. Pinitpaitoon et al. (2011) outlined a framework for determining how much substitution of chemical fertilizer occurs with organic fertilizer materials.

Table 15 shows the overall calculations (ignoring cost of compost preparation due to unavailable data) of money savings due to use of compost fertilizer at household level. If a farmer having few cattle heads and cultivable lands, he/she can prepare compost using household agricultural waste that can save money and improve soil health. The survey reveals that the average 0.822 tons of compost used in each household can reduce the chemical fertilizer cost of total Tk. 1462/HH per month of which Tk.192 from urea, Tk. 445 from TSP, Tk. 166 from MoP, Tk.198 from Gypsum, Tk. 351 from ZnSO4, and Tk. 110 from Boric acid.

Table 15. Equivalent fertilizer and money saved due to use of compost

Particulars	Urea	TSP	MoP	Gypsum	ZnSO4	Boric acid	Total Tk.
Fertilizer saved (kg/ton)							
Decomposed cowdung	12.37	14.00	6.80	9.99	2.09	0.29	--
Scientifically prepared compost	13.24	19.50	11.60	13.88	1.95	0.35	--
Vermicompost	18.23	31.50	19.40	24.42	2.22	0.41	--
All types of compost (Average)	14.61	21.67	12.60	16.10	2.09	0.35	--
Retail price (Tk/kg)	16.00	25.00	16.00	15.0	205.00	380.00	--
Money saved (Tk./ton)							
Decomposed cowdung	198	350	109	150	428	110	1345
Scientifically prepared compost	212	488	186	208	400	133	1626
Vermicompost	292	788	310	366	455	156	2367
All types of compost (Average)	234	542	202	242	428	133	1780
Money saved (Tk./HH/month)							
Fertilizer saved from agricultural waste/compost (kg/HH/month)*	12.01	17.81	10.36	13.23	1.71	0.29	--
Money saved (Tk./HH/month)	192	445	166	198	351	110	1462

Note: Authors' calculation with the help of Appendix Tables 6 & 7
*The average amount of agricultural waste is 822 kg/HH/month (see Table 6)

5.0 CONCLUSIONS

The present study has tried to find out the types of agricultural waste materials available for recycling and their utilization pattern at farm household level, by surveying 300 households in 5 districts of Bangladesh. The study has found a considerable amount of agricultural waste produced at household level from different sources such as cowdung, goat and chicken manure, kitchen waste, cattle feed and fodder waste, household garbage, rice and wheat husk, etc. The highest proportion of total available wastes comes from cowdung followed by cattle feed and fodder refusal, household garbage and kitchen waste. Most farmers have stored non-used cowdung and other wastes in pit or heap for decomposition and used as an organic fertilizer. The second highest use of dry cowdung is cooking fuel. The uses patterns of cowdung vary throughout the year depending on season or weather condition. The uses of the remaining agricultural wastes were for cooking fuel, cattle feed, and composting depending on the type of the waste. However, some farmers throw the wastes into open ditches or surrounding areas. Most of the farmers were not much aware of utilizing household wastes properly and do not follow the scientific methods of compost preparation.

Based on the findings of the study, the following recommendations may be considered for proper utilization of household wastes and further study on this issue.

- Farmers having some crop lands with 2-5 head of cattle should be provided training on awareness raising for quality compost preparation.
- Necessary steps should be taken by the Department of Agricultural Extension to develop some entrepreneurs who will collect agricultural waste from different households and prepare compost (including vermicompost) at the community level on commercial basis.
- Entrepreneur should be provided short-term loan facility with low interest rates for operating business on compost preparation and marketing.

- Further study is needed on this issue to calculate the profitability of scientifically compost preparation in order to formulate a business model on compost preparation and marketing at community level.

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Appendix Tables

Table 1. Annual cowdung use in Barguna district

Period of time	Dried for fuel		Storing in pit or heap	
	% responses	% used	% response	% used
Mid-April to mid-May	--	--	100	100
Mid May to mid-June	--	--	100	100
Mid-June to mid-July	--	--	100	100
Mid-July to mid-August	--	--	100	100
Mid-August to mid-September	50	50	50	50
Mid-September to mid-October	100	100	--	--
Mid-October to mid-November	100	100	--	--
Mid-November to mid-December	100	100	--	--
Mid-December to Mid-January	100	100	--	--
Mid-January to mid-February	100	100	--	--
Mid-February to mid-March	100	100	--	--
Mid-March to mid-April	100	100	--	--

Table 2. Annual cowdung use in Khulna district

Period of time	Dried for fuel		Prepare compost	
	% response	% use	% response	% use
Mid-April to mid-May	16	14	88	86
Mid May to mid-June	16	13	88	87
Mid-June to mid-July	16	14	88	86
Mid-July to mid-August	16	14	88	86
Mid-August to mid-September	16	14	88	86
Mid-September to mid-October	22	20	82	80
Mid-October to mid-November	78	76	26	24
Mid-November to mid-December	92	90	12	10
Mid-December to Mid-January	94	92	10	8
Mid-January to mid-February	94	92	10	8
Mid-February to mid-March	94	92	10	8
Mid-March to mid-April	94	92	10	8

Table 3. Annual cowdung use in Mymensingh district

Period of time	Dried for fuel		Prepare compost		Storing in pit/heap	
	% response	% used	% response	% used	% response	% used
Mid-April to mid-May	38	33	70	62	8	5
Mid May to mid-June	36	29	72	64	6	7
Mid-June to mid-July	8	9	86	85	8	6
Mid-July to mid-August	6	8	82	85	6	7
Mid-August to mid-September	6	8	86	86	8	6
Mid-September to mid-October	22	20	80	75	8	5
Mid-October to mid-November	38	34	70	64	2	2
Mid-November to mid-December	44	39	64	58	4	3
Mid-December to Mid-January	36	33	70	65	2	2
Mid-January to mid-February	36	32	72	65	4	3
Mid-February to mid-March	42	38	68	60	2	2
Mid-March to mid-April	44	41	62	57	4	2

Table 4. Annual cowdung use in Rajshahi district

Period of time	Dried for fuel		Prepare compost		Storing in pit		As fish feed	
	% response	% use	% response	% use	% response	% use	% response	% use
Mid-April to mid-May	55	51	45	49	--	--	--	--
Mid May to mid-June	47	46	53	54	--	--	--	--
Mid-June to mid-July	15	14	80	81	3	3	2	2
Mid-July to mid-August	7	3	85	90	3	4	5	3
Mid-August to mid-September	10	9	86	87	2	2	2	2
Mid-September to mid-October	25	24	70	74	3	--	2	2
Mid-October to mid-November	50	51	49	47	--	1	1	1
Mid-November to mid-December	75	75	25	25	--	--	--	--
Mid-December to Mid-January	80	79	20	21	--	--	--	--
Mid-January to mid-February	86	85	14	15	--	--	--	--
Mid-February to mid-March	87	87	13	13	--	--	--	--
Mid-March to mid-April	80	79	20	21	--	--	--	--

Table 5. Annual cowdung use in Thakurgaon district

Period of time	Dried for fuel		Prepare compost	
	% response	% use	% response	% use
Mid-April to mid-May	10	5	90	95
Mid May to mid-June	16	4	84	96
Mid-June to mid-July	18	3	82	97
Mid-July to mid-August	20	6	80	94
Mid-August to mid-September	10	3	90	97
Mid-September to mid-October	18	3	82	97
Mid-October to mid-November	14	7	86	93
Mid-November to mid-December	10	7	90	93
Mid-December to Mid-January	20	8	80	92
Mid-January to mid-February	16	10	84	90
Mid-February to mid-March	14	8	86	92
Mid-March to mid-April	16	7	84	93

Table 6. Nutrient composition in decomposed cowdung, scientifically prepared compost and vermicompost

Compost type	Amount (kg/ton)						
	N	P	K	S	Zn	B	Mg
Decomposed cowdung	5.7	2.8	3.4	1.8	0.75	0.05	2.2
Scientifically prepared compost (compost rural)	6.1	3.9	5.8	2.5	0.70	0.06	10.5
Vermicompost	8.4	6.3	9.7	4.4	0.80	0.07	13.0

Source: Annual Report, 2018-19, Soil Science Division, BARI, Gazipur

Table 7. Fertilizer nutrient ratio

Nutrient (kg/ha)	Fertilizer (kg/ha)	Fertilizer/Nutrient ratio
N =116	Urea =252.24	2.17
P = 16.1	TSP = 80.5	5.00
K=70.3	MoP = 140.6	2.00
S =12.82	Gypsum = 71.2	5.55
Zn =1.04	Zinc sulphate (heptahydrate) = 4.95	4.75
B = 0.502	Boric acid = 2.95	5.88

Source: Fertilizer Recommended Guide (FRG), 2018, BARC, Farm gate, Dhaka.

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Availability and utilisation pattern of agricultural waste at household level in selected areas of Bangladesh

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Abstract

The use of organic fertilisers and soil amendments are almost universally recommended for improving the organic matter levels and maintaining soil health, but few studies documenting the actual availability and quality of such materials on smallholder farms are available. We selected a case study of 300 households from northern and southern Bangladesh to assess the types of waste materials available for recycling and their usage patterns at household level and we applied a novel approach to empirically identify household waste as input inefficiency in a production context. Northern districts have highly intensive farming systems whereas southern districts have low intensity farming. The total amount of agricultural waste produced at household level was estimated at 822 kg per month. Cow dung contributed about 65% of the total waste followed by animal feed refusal waste (11%), garbage (7%) and kitchen waste (6%). Most of the farmers utilised cow dung and wastes as organic fertiliser and lesser amounts as cooking fuel. Econometric analysis shows that the number of cattle and small ruminant per holding, total area of cultivated land and family size were significant factors that influence the amount of waste production at household level. Each household can reduce the chemical fertiliser cost by Tk. 1463 (US$ 17.84) per month by using compost prepared from household waste. There were ample opportunities for compost/vermicomposting and potential markets. The Department of Agricultural Extension from the public sector and private sector agents might motivate farmers to harvest the potential benefits of agricultural waste through effective management and utilisation.

Keywords

Agricultural waste management, utilisation, potential benefits, organic fertiliser, households

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Introduction

Soil degradation due to organic matter depletion remains a concern for crop production in many places globally (Zahid et al., 2011). An organic matter content more than 3.5% is proposed to maintain soil fertility and crop productivity (Johnston et al., 2009). The overall organic matter content is usually low in the agriculturally important soils in Bangladesh (Moslehuddin and Laizoo, 1997). Most soils of Bangladesh have less than 1.7% organic matter content and in some areas, soils have less than 1% organic matter (Hossen et al., 2015; Islam, 2006). Addition of organic materials to the soil is almost universally recommended to boost organic matter content in the soil and improve soil health (Ayilara et al., 2020). Both the global and national evidence reconfirm that agricultural wastes can be converted into organic compost (Higgins et al., 2007) and utilised to enhance soil health (Brockwell and BottomIey, 1995; Islam et al., 2018; Shinde and Patil, 2016), which boosts crop production (Cardona et al., 2010). Agro-wastes are the cheapest source to improve the fertility of soil (Gupta et al., 2016; Lim and Matu, 2015). The organic fraction of bio-resources in rural areas represents a valuable resource, which could be recycled and transformed into nutrient-rich fertiliser or soil conditioner (Bernstad et al., 2016; Calabi-Floody et al., 2018). The most commonly used organic matter is the farmyard manure but there can be a wide variation in composition of farmyard manure and between the requirement of crops and the availability of nutrients in the manure. The transformation of organic materials through composting or vermicomposting can increase their nutrient concentrations and their suitability as organic fertilisers.

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Farm households in their daily activities are major generators of agricultural wastes, in the form of manure, crop residues or mixed solid wastes. Animal waste, a large component of agricultural waste, includes (i.e. feed waste, bedding and litter, and feedlot and paddock) runoff from livestock, dairy and other agricultural practices. However, there is little information about the stocks of organic materials available on smallholder farms in the Eastern Gangetic Plain, or their potential for use as soil amendments of organic fertilisers.

Biological degradation during composting and vermicomposting are strategies to transform these organic wastes into organic amendments (Barthod et al., 2018). Composting can play an important role in farm households by reducing environmental threats linked to improper organic waste management and improving soil fertility, which will have immediate impact upon crop productivity (Mohee, 2007). Farm households in the rural areas generally gather agricultural waste from different agricultural activities and put them together in a pit and use it later as compost in crop field. Rarely, they sell decomposed agricultural waste for earning cash. In most cases, farmers do not follow scientific methods for composting of agricultural or solid waste that creates many environmental and health hazards (Alam and Ahmade, 2013). In Bangladesh, inappropriate waste management systems and lack of government and community support make the composting process difficult (Sultana et al., 2020). The knowledge-base of farmers and motivation of professional cooperative organisations were crucial for appropriate agricultural waste management.

Nevertheless, data and information regarding agricultural waste availability, its processing, storage and utilisation at household by smallholder farms and in the community are scarce in Bangladesh. Hence, this article documents the availability of waste generated from crop cultivation, livestock production and agricultural service activities and evaluates potential benefits through utilisation in rural Bangladesh. The aim of this article is to assess the potential benefits of agricultural waste for smallholders' farms through effective management and utilisation and determine the policy implications of this resource.

Materials and methods

Data sources

The data were collected in six Upazilas (sub-district or an administrative unit of a district) of five districts (Durgapur and Godagari Upazilas of Rajshahi, Sadar Upazila of Thakurgaon, Sadar Upazila of Mymensingh, Dacope Upazila of Khulna and Amtali Upazila of Barguna) in northwest and southern Bangladesh (See Figure 1.). These Upazilas were selected because of existing activities of the Nutrient management for diversified cropping in Bangladesh (NUMAN) project. The project has facilitated several interventions related to soil health and fertiliser management including compost preparation in these study areas. The selected study districts are circle in red colour shown in the map. Two agricultural blocks (areas of 1000–2000 ha) from each Upazila were selected for farm household survey. In each block, 25 households were identified that are engaged in crop farming and holding at least two cattle. A total of 300 households were interviewed through a pre-tested interview schedule. For collecting data, a comprehensive 2-day long training workshop on the data collection procedure was held for the recruited survey enumerators. To ensure a uniform pattern in administering the survey, skill training in the field situation was emphasised. The personnel of the NUMAN Project in the respective study areas, Conservation Agriculture Service Providers' Association (CASPA) and DAE (Department of Agriculture Extension) personnel assisted researchers and enumerators in collecting primary data. Secondary data were collected from the Fertilizer Recommendation Guide (FRG, 2018) and the annual report of Soil Science Division of Bangladesh Agriculture Research Institute.

Analytical technique

As soon as the filled-out interview schedules were returned from the field, they were sorted based on identification criteria. The sorted and identified schedules were handled carefully during data-processing stage with direct supervision of the research team. Collected data were scrutinised for errors (e.g. inaccuracy, incompleteness, inconsistencies, local units), coded, cleaned and entered into MS Excel and then exported to the Statistical Package for the Social Sciences (SPSS). Mostly, descriptive statistics were used for analysing the collected data using SPSS software (Version 20). In addition, a multiple linear regression model was used to identify factors affecting the amount of agricultural waste at household level:

$$Y = a_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + \cdots u_i$$

where, Y = Amount of agricultural waste at household level (kg month^{-1})

a_0 = Constant term (Y-intercept)

x_1 = No. of cattle per household

x_2 = No. of goat or sheep per household

x_3 = No. of poultry per household

x_4 = Cultivated land (decimal per household)

x_5 = No. of family member per household

b_1, b_2, b_3, b_4 and b_5 are the slope coefficients of each explanatory variable

u_i = the model's error term

Results and discussion

Land and livestock holding

Land is the most important asset for farm households because farm families mostly depend on the land. The quantity of agricultural waste of a household also depends on cultivated land area. Average cultivated land of all respondent farmers was 0.74 ha per household with the minimum and maximum areas of 0.19 ha and

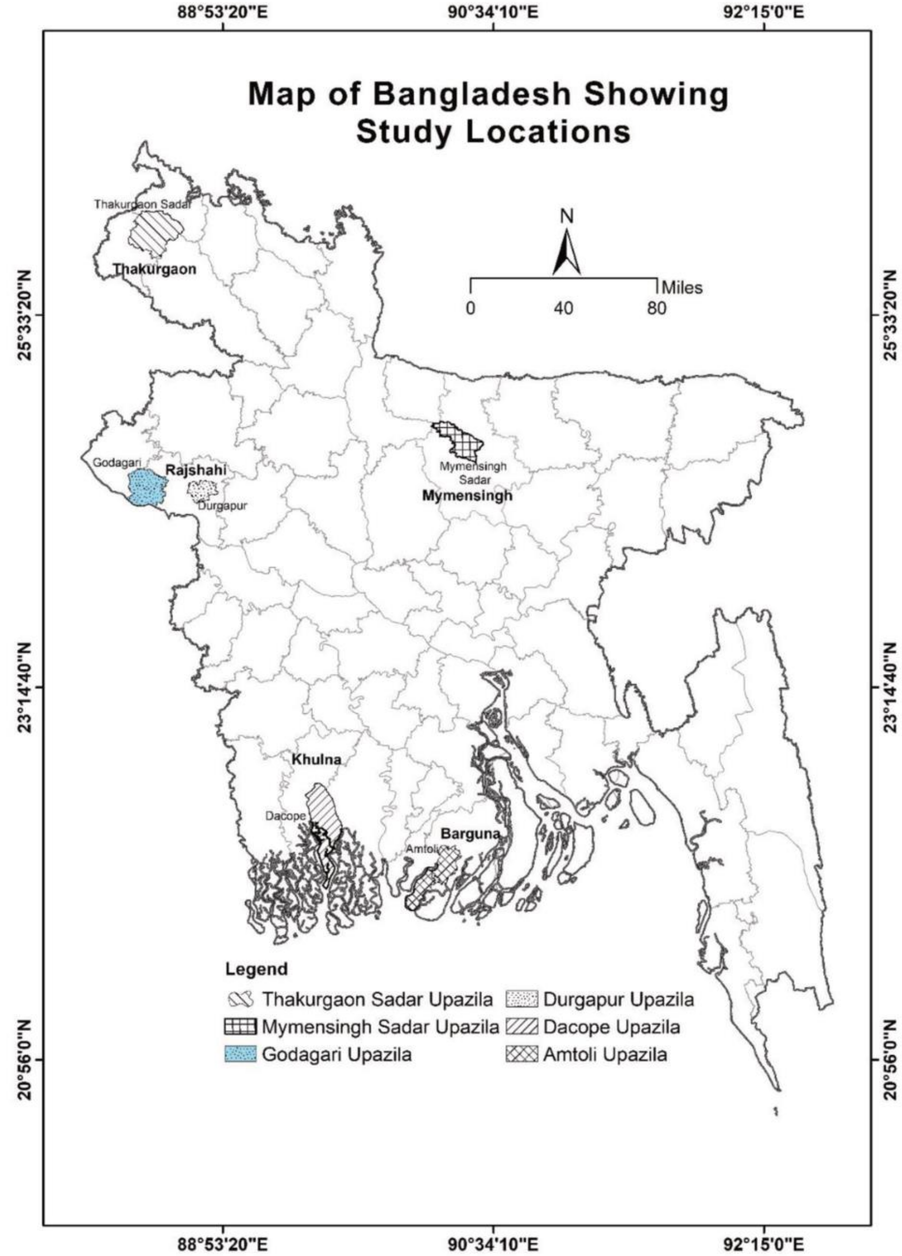

Figure 1. Study locations indicated in different colours and patterns.

2.61 ha per household, respectively (Table 1). Across the study areas, the largest cultivated land size was observed in Mymensingh district (1.13 ha household^{-1}) followed by Rajshahi (0.89 ha household^{-1}) and Thakurgaon districts (0.63 ha household^{-1}), Khulna (0.57 ha household^{-1}), and the smallest (0.36 ha household^{-1}) in Barguna district.

The average holdings of the adult cattle (age > 1 year) and calves (age ≤ 1 year) were 2.97 and 1.06 per household in the study areas, respectively. At the national level, the number of cattle per household was estimated at 1.47 (BBS, 2019), which is a bit lower than that of sample households. In the case of small ruminants (goat or sheep) and poultry, the average holdings were 2.35 and 16.6 per household, respectively. By comparison, nationally average number of goat or sheep and chicken were 1.81 and 17.9, respectively (BBS, 2019). Rajshahi farmers owned the highest number of cattle (3.38 per household) followed by the

Table 1. Average cultivated land area per household (ha) and livestock holding in the sample households.

	Barguna (*n* = 50)	Khulna (*n* = 50)	Mymensingh (*n* = 50)	Rajshahi (*n* = 100)	Thakurgaon (*n* = 50)	All (*n* = 300)
Cultivated land area	0.36	0.57	1.13	0.89	0.63	0.74
Livestock holding per household						
Cattle (> 1 year)	2.42	2.98	2.44	3.38	3.24	2.97
Calf (⩽ 1 year)	1.90	0.84	1.06	0.84	0.86	1.06
Goat or sheep	2.60	2.16	1.20	2.50	3.12	2.35
Chicken	44.1	10.2	12.4	12.6	7.82	16.6
Cattle penning at homestead (hour day^{-1})	14.9	19.0	18.9	21.5	17.0	18.8

Table 2. Monthly quantity (kg) of types of agricultural waste produced per household in five study districts.

Types of agricultural waste	Barguna (*n* = 50)	Khulna (*n* = 50)	Mymensingh (*n* = 50)	Rajshahi (*n* = 100)	Thakurgaon (*n* = 50)	All area (*n* = 300)	Amount (kg livestock $^{-1}$)
Cow dung	403.2	533.4	465.0	590.1	613.8	532.6	132.2
Goat and chicken manure	44.3	8.6	13.4	23.4	33.1	24.4	1.3
Kitchen waste	65.4	51.4	33.4	55.3	37.8	49.8	–
Cattle feed waste	105.6	92.4	76.8	89.1	104.7	93.0	23.1
Household garbage	52.8	25.5	55.9	45.8	97.2	53.8	–
Rice/wheat husk	15.8	14.5	13.6	17.6	32.0	18.5	9.5
Kitchen and bush ash	84.5	22.2	24.4	53.2	61.3	49.8	0
All wastes	771.6	748.0	682.5	874.5	979.9	821.9	–

farmers of Thakurgaon (3.24 per household and Khulna (2.98 per household) districts. Although the average holding of cattle per household was lowest in Barguna district, the average holdings of the small ruminant (goat or sheep) and poultry were highest in this district (Table 1).

The duration of cattle penning around the house has a positive association with the availability of waste. Among the study areas, cattle were kept for the longest period (21.5 hours day^{-1}) in Rajshahi district followed by Khulna (19.0 hours day^{-1}) and Mymensingh district (18.9 hours day^{-1}) and the lowest in Barguna district.

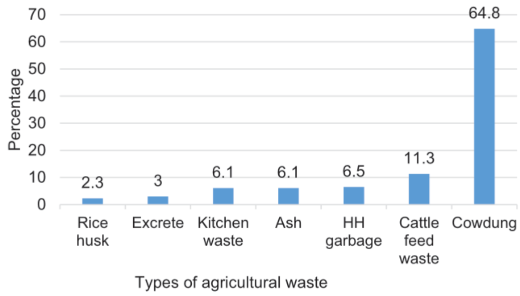

Figure 2. Percent share of agricultural waste in households in five study areas of Bangladesh.

Availability of agricultural waste

Generally, seven types of agricultural wastes were produced or available at farm household level (Table 2). The average amount of waste produced per household was 822 kg per month. The highest amount of agricultural waste produced was in Thakurgaon district (980 kg household month^{-1}) followed by Rajshahi (875 kg household month^{-1}) and Barguna district (772 kg/household month^{-1}). Cow dung contributed the highest share (65%) to the total waste followed by cattle feed waste (11%), household garbage (7%) and kitchen waste (Figure 1). Among the study areas, the highest quantity of cow dung was found in Rajshahi district (590 kg household^{-1} month^{-1}) due to holding higher average number of cattle (Table 2) and their longer period in pens at the homestead (Table 2). Akhter et al. (2016) found average amount of cow dung produced per household was 266 kg month^{-1} while this study estimated 132.2 kg month^{-1}. This decrease may be attributed to differences in cattle breed, penning duration and age of the cattle. The average amount of excreta produced from small ruminants (goat or sheep) was estimated at 24.4 kg (3.0% of the total waste) per month. The amount of excreta was highest in Barguna district and the lowest in Khulna district. The average amounts of cattle feed waste, kitchen waste and household garbage were estimated at 93 kg (11.3%), 49.8 kg (6.1%), and 53.8 kg (6.5%) per month household^{-1}, respectively.

Among seven different sources of agricultural waste, cow dung alone contributes two-third of the total agricultural waste (Figure 2). The second most abundant contributor was the cattle feed waste (11.2%) followed by household garbage (6.5%), ash & kitchen waste jointly (6.1%), excreta (3%) and rice husk (2.3%), respectively. In fact, cow dung is an important source of nitrogen (N) for crop production and enables farmers to reduce inputs of commercial fertiliser, thereby increasing the profit of the farmer (Islam et al., 2018).

Table 3. Factors affecting the quantity of agricultural waste at household (HH) level.

Variable	Coefficient	Std. error	*t*-value	*p*>|t|
Constant	351.9***	30.65	11.48	0.000
Cattle holding (No. household^{-1})	114.5***	4.72	24.24	0.000
Goat/sheep holding (No. household^{-1})	9.22*	4.99	1.85	0.065
Poultry holding (No. household^{-1})	0.33	0.84	0.40	0.692
Cultivated land (decimal household^{-1})	0.21**	0.09	2.26	0.025
Family size (No. household^{-1})	25.7**	10.80	2.38	0.018
F-value	141.4***			0.000
R^2	0.706			
Adjusted R^2	0.701			
N	299			

Dependent variable: Amount of agricultural waste (kg month^{-1}).
*Represent 10% level of significance.
**Represent 5% level of significance.
***Represent 1% level of significance.

Factors of production of waste at household level

A functional analysis was applied to identify the factors affecting waste production at farm household level and the results of this analysis are presented in Table 3. The number of cattle and small ruminants (goat or sheep) per household, total area of cultivated land, and family size were significant factors that influence the amount of waste production at household level. As for example, the coefficient of cattle holding is 114.5 and significant at 1% level, which implies that an increase of cattle holding by one unit, keeping other factors constant, would increase household waste production by 114.5 kg month^{-1} across all five study districts. Similarly, the coefficient of family size is 25.7 and significant at 5% level indicating that an increase of family size by one unit, keeping other factors constant, would increase household waste production by 25.7 kg month^{-1} overall. The variables included in the model explained 70% of the variation in farm household level waste production.

Utilisation of agriculture waste

Cow dung is mainly used as organic fertiliser, household fuel and for compost production in the study areas. Generally, farmers collect cow dung everyday morning and afternoon, while for poultry litter they usually clean twice in a week and for kitchen waste once in day. Dried cow dung is a common fuel in most of the study areas. Sample farmers collected and dried cow dung mostly in the winter season for fuel, sometimes after being mixed with straw. Pieces of dry dung are lit to provide heat and a flame for cooking. In fact, farmers are keen to use cow dung as a source of energy due to unavailability of other energy sources. A few farmers also use it as fish feed (Table 4). Most respondent farmers (58%) in the study areas used cow dung for preparing compost that was used as a fertiliser. Field experiment in Nigeria shows that cow dung produced higher yield (3.5 tonne ha^{-1}) of tomato compared to control plot (1.2 tonne ha^{-1}; Usman, 2015). Cow dung is a cheap and economically viable resource, which is easily available (Gupta et al., 2016). However, the collected cow-dung in rainy season (mid-April to mid-August) is generally thrown in an open pit or kept in a heap for de-composition (sometimes farmers also considered it as compost), which can cause nutrient losses (Hoang et al., 2015). Cow dung could be used for preparing vermicomposting that has potential market in some of the study areas (Haque et al., 2018). Vermicomposting needs technical know-how and financial assistance that were absent in most the study areas.

Goats produce comparatively neat pelletised droppings that do not typically attract insects or burn plants as does manure from cows or horses. It is virtually odourless and is beneficial for the soil (Tilley, 2019). The most common use of goat manure is as an organic fertiliser. It can help farmers produce healthier plants and crop yields. Chicken manure has the highest amount of N, potassium and phosphorus among all animal manures (Barrett, 2008; Martin and Gershuny, 1992). It is used also as an organic fertiliser, especially for soils low in N (Mick, 2015). Chicken manure can be used to create homemade biofertiliser (Patricia and Cheryl, 2013). A study conducted in the Philippines showed that the use of chicken manure as a fertiliser in milkfish production in brackish water ponds performed the best after cow manure (Garcia et al., 2007). More than half of the respondent farmers in the study areas used goat and chicken manure for compost preparation. On an average, 35% farmers discard goat and chicken manure possibly due to small quantities produced or putting less importance on it.

Household waste, also known as domestic waste, comprises disposable materials generated by households, which may be non-hazardous waste or hazardous waste. This study identified non-hazardous waste including food scraps, unused cattle feed and fodder, garbage, rice husk, ash, paper, bottles and metallic and non-metallic items, which can be recycled or composted. Kitchen waste includes vegetable peelings, fruit waste (apple pumice, banana peels and so on), cheese rind and unused cooked and uncooked food. About 44% of the respondent farmers in the study areas ignored the importance of kitchen waste and discarded them. On an average, 36% farmers used kitchen waste as

Table 4. Percentage of responses regarding agricultural waste utilisation in the study areas.

Sources of waste	Dried for fuel	Compost	Storing in pit heap^{-1}	Used as fish feed	Discard	Animal feed
Cow dung	42	58	8	0.2	–	–
Goat and chicken manure	–	54	11	–	35	–
Kitchen waste	–	16	4	–	44	36
Cattle feed waste	37	20	–	–	43	–
Household garbage	23	16	–	–	61	–
Rice husk	50	11	–	–	–	39
Kitchen/bush ash	–	43	12	–	47	–

cattle feed and 16% used it for compost preparation. Only 4% of farmers added kitchen waste to the cow dung heap (Table 4).

The amount of uneaten animal feed or fodder is classified as refusal and wastage. Refusal is material that remains in the feed and fodder basket, on pasture or on bare ground, which was not consumed by cows after a certain period of time following the feed-out. The refusal may or may not be eaten at a later stage. Wastage is the amount of feeds and fodder that are contaminated with urine or faeces and soil or spread out around the feed-out area and will not be eaten by cows at a later stage. The amount of feed and fodder wastage depends on many factors such as feeding methods, intervals between feedings, amount fed at a time, climatic conditions, number of cattle being fed, access of cattle to feed and fodder, competition for the feed and fodder quality (DAGF, 2009). Overall 43% of respondent farmers in the study areas discard the feed and fodder waste, 37% used it as fuel and 20% used it for preparing compost (Table 4).

Household garbage includes paper, cardboard, paper carton, plastic, polybags, metals, glass, electronic waste, plaster from coatings of walls, wood, hazardous waste, food waste, crop residues, dust, and so on. (Table 4). Most of the respondent farmers throw such garbage into open spaces adjacent to the homestead in open ditches in the surrounding areas. Only 23% and 16% of the respondent farmers used some of the garbage as fuel and green garbage for preparing compost, respectively.

Rice husk are the hard protective coverings of *rice* grains that are separated from the grains during the process of milling. It is a cellulose-based material but contains 20% silica in amorphous form (Hu et al., 2008; Mansaray and Ghaly, 1998; Nair et al., 2008; Ndazi et al., 2007). About half of the respondent farmers in the study areas used rice husk as cooking fuel, especially for parboiling rice. Due to its nutritive value, about 39% farmers used it as cattle feed. Only 11% farmers used rich husk as an ingredient for compost preparation by mixing with cow dung.

Ash is the powdered residue left after the burning wood, bamboo, dry leaves, paper, dry dung, jute stick, paddy husk, dry cow dung, and so on. It serves as a source of potassium and calcium carbonate, the latter acting as a liming agent to neutralise acidic soils (Lerner, 2000). In many cases, ash can be used as an organic or inorganic fertiliser to enrich soil nutrition. The combined use of lime, cow dung manure and kitchen ash increased the yield and yield components of faba bean in Ethiopia (Asrat et al., 2020). Ash effectively reduced the damage of insects to maize grains (Golob and Hanks, 1990). Many farmers traditionally use ash to protect stored commodities from bruchid damage during storage (Golob et al., 2002). About 47% respondent farmers stated that they had little use of ash and in most cases they throw it out. A minor portion of farmers use ash as litter in poultry farms (Table 4).

Economics of compost use in crop production

Plants generally get only one (sometimes more) nutrient from individual chemical fertiliser products, but organic fertiliser supplies most of the essential nutrients to the plant. For instance, urea fertiliser supplies only N, whereas decomposed cow dung supplies almost all the essential plant nutrients including N. Hence, Integrated Plant Nutrition System (IPNS) suggests to use both chemical and organic fertilisers aiming to reduce the use of chemical fertilisers for crop production and improve the soil health (FRG, 2018).

Farmers can reduce the use of chemical fertilisers as well as save the cost of crop cultivation by using compost from agricultural household waste in crop farming. Ye et al. (2020) reported that in both the pot and field trials reduced rates of chemical fertiliser plus bio-organic fertiliser produced tomato yields equivalent to those obtained using 100% of the chemical fertiliser. Similarly Geng et al. (2019) compared chemical fertiliser treatments; equal amounts of substitutions with cow manure or chicken manure increased production and a 25% nutrient substitution resulted in the best yield increase. Straw return had no effect on maize production, and 100% straw return resulted in reduced production.

In this study, calculation is made based on FRG 2018. For example, cow dung (decomposed) contains moisture (35±3.5%), N (1±0.1%), P (0.3±0.03%) and K (0.46±0.05%), respectively. Similarly, farmyard manure contains moisture (67±6.7%), N (1.6±0.16%) P (0.83±0.08%) and K (1.7±0.17%), respectively (FRG, 2018 page 197). If the recommended dose of inorganic fertiliser is 120 kg N ha^{-1}, 5 tonne of cow dung supplies 25 kg N ha^{-1} that can be reduced from total N fertiliser input. Hence, (120−25) kg = 95 kg ha^{-1} N will be required from inorganic fertiliser. Therefore, the cost of 25 kg N, equivalent to 54.34 kg of urea (46% N) is (Tk. 16 × 54.34 kg) = Tk. 870 ha^{-1} that can be saved. Like N, the other nutrients can be reduced by using organic

Table 5. Equivalent fertiliser and money saved due to use of compost at 5 tonne ha^{-1}.

Particulars	Urea	TSP	MoP	Gypsum	ZnSO4	Boric acid	Total Tk.
Fertiliser saved (kg tonne^{-1})							
Decomposed cow dung	12.37	14.00	6.80	9.99	2.09	0.29	–
Scientifically prepared compost	13.24	19.50	11.60	13.88	1.95	0.35	–
Vermi-compost	18.23	31.50	19.40	24.42	2.22	0.41	–
All types of compost (average)	14.61	21.67	12.60	16.10	2.09	0.35	–
Retail price (Tk kg^{-1})	16.00	25.00	16.00	15.0	205.00	380.00	–
Money saved (Tk. tonne^{-1})							
Decomposed cow dung	198	350	109	150	428	110	1345
Scientifically prepared compost	212	488	186	208	400	133	1626
Vermi-compost	292	788	310	366	455	156	2367
All types of compost (average)	234	542	202	242	428	133	1780
Money saved (Tk. household^{-1} month^{-1})							
Fertiliser saved from agricultural waste/ compost (kg household^{-1} month^{-1})*	12.01	17.81	10.36	13.23	1.71	0.29	–
Money saved (Tk. household^{-1} month^{-1})	192	445	166	198	351	110	1462

TSP: triple super phosphate; MoP: muriate of potash.
Authors' calculation. *The average amount of agricultural waste is 822 kg household^{-1} month^{-1}.

fertiliser, which can save money from less inorganic fertiliser use. Pinitpaitoon et al. (2011) outlined a framework for determining how much substitution of chemical fertiliser occurs with organic fertiliser materials.

Table 5 shows the overall calculations (ignoring cost of compost preparation due to unavailable data) of monetary savings due to use of compost fertiliser at household level. If a farmer having a few cattle head and cultivable land can prepare compost using household agricultural waste, then that can save money and improve soil health. The survey reveals that the average 0.822 tonne of compost used in each household can reduce the chemical fertiliser cost of total Tk. 1462 per household per month of which savings comprised of Tk.192 from urea, Tk. 445 from TSP (triple super phosphate), Tk. 166 from MoP (muriate of potash), Tk.198 from gypsum, Tk. 351 from zinc sulphate, and Tk. 110 from boric acid.

Conclusion

The types of agricultural waste materials available for recycling and their utilisation pattern on farms by smallholder households were reported for five study areas in rural Bangladesh. Almost 10 tonnes of agricultural waste was produced annually by a single household from sources such as cow dung, goat and chicken manure, kitchen waste, cattle feed and fodder waste, household garbage, rice and wheat husk and so on. The highest proportion of total available wastes comes from cow dung followed by cattle feed and fodder refusal, household garbage and kitchen waste. The agricultural waste is a potential resource containing nutrients and organic matter. However, continuous recycling of agricultural wastes without careful separation of hazardous materials might adversely affect soil health. There is a great scope to increase management skills to enhance the value of agricultural waste. Hence, the following suggestions are proposed for effective management of agricultural waste.

- As farmers have limited skills on preparing quality compost, farmers having some crop lands with two to five head of cattle should be provided training and awareness raising for quality compost preparation.
- Department of Agricultural Extension might encourage local entrepreneurs for preparing quality compost (including vermicompost) at community level on a commercial basis. They might aggregate raw material from the farm households. In addition, local entrepreneurs should be provided short-term loan facilities with low interest rate for operating business on compost preparation and marketing.
- Government of Bangladesh is providing huge subsidy for chemical fertilisers. The subsidy for quality compost and vermicompost fertilisers are essential for popularising and commercialisation.
- Further study is needed on this issue to calculate the profitability of scientific compost preparation to formulate a business model on compost preparation and marketing at community level.

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