Field Performance of Mini Combine Harvester Utilized for Rice Harvesting in Haor Areas of Bangladesh

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***Abstract*—** The study was undertaken to evaluate the technical and economic performance of Sifang brand rice combine harvester in the haor area during the Boro season, 2020. Data on field capacity, time distribution in the harvesting loss, turning events, forward speed, fuel consumption, loss in harvesting, cost distribution and break-even area were collected. Harvesting speed ranged from 1.40-1.90 km h-1 and actual field capacity ranged from 0.09-0.12 ha h-1. Harvester machine was operated 1 (low) gear position. Crop density was observed higher, and the machine was operated at low speed to avoid clogging in the feeding section. The size of the land should be at least 500 m2 to operate the Sifang combine harvester having a cutting width of 1m at full capacity. Sifang combine harvester should be run the field having more than 25 m length. Combine harvester spent 45% time in harvesting¸ 17% time in turn, and the remaining 38% of the total time was expended in repairing, idle, work stop due to rain. The average fuel consumption was recorded as 17 l ha-1. The harvesting loss was observed at 2.13%. Grain was spilled away while gathering cut crops due to a lack of proper inclination of the header unit. The power delivery system should be modified to get the desired performance. The combine harvester was unable to develop sufficient traction in soft soil during the harvesting period in the haor area. The break-even area of the combine harvester was 7.5 ha. The combine harvester ought to be assessed under a wide scope of crop and soil conditions across various agro-ecological zones of Bangladesh. This would offer smallholder farmers assorted alternatives of rice harvesting mechanization to encourage future adoption of improved harvesting innovations.

***Keywords*—** Field capacity, field efficiency, time loss, grain loss, break-even area.

I. INTRODUCTION

Haors are wetland ecosystems with unique hydro-biological qualities positioned in the northeastern region of Bangladesh, covering about 1.99 million ha of territory (CGIS, 2012). There are approximately 373 haors situated in the districts of Habiganj, Moulovibazar, Brahmanbaria, Kishoreganj, Sylhet, Netrakona, and Sunamganj districts. During monsoon, haors obtain surface runoff water from rivers and canals to emerge as substantial stretches of turbulent water. Rice cultivating, particularly Boro rice, is the main yield delivered every year in the haor region. This Boro rice harvesting stays under the steady danger of partial to complete loss from the early stage on the surge of flash floods. Developments in the agriculture sector through the mechanized way can lead to an increase the rice production, rural employment, and poverty reduction in these regions. In these cases, timely rice harvesting is a major task to avoid the risk of crop damage due to early rains or flash flooding.

Harvesting is a labor-intensive operation in rice cultivation and required 61 man-days ha-1 labor (Hasan et al., 2019). Farmers in the haor region wholly depended on the migrated labor to complete the harvesting task. Harvesting operations are classified as; manual (harvesting by sickle, carrying by head and shoulder, threshing by hand beating or power tiller trading), semi-mechanized (harvesting by sickle, transporting by head and shoulder and trolley, threshing by thresher either by close drum or open drum thresher) and mechanized (harvesting, threshing, winnowing and bagging by combine harvester) process. Shifting of labor from on-farm to off-farm activities is the major reason for the labor shortage at the peak period of rice harvesting.

Combine harvesters perform a vital in harvesting operation as they offer timely harvesting and keep up good paddy quality (Yousif and Babiker, 2018). Islam et al. (2020) stated that the harvester is an effective, economic, labor cost, and time- saving technology, but its primary investment is very high. Many factors govern the profitable operation of harvester such as land size, machine accessibility, field to field distance, crop characteristics, soil and weather conditions, readiness and management practices, as properly as financial features (Islam, 2016; Yousif and Babiker, 2018). Size, shape and length of harvesting field affected the overall performance of combine harvester during operation

(Bhuiyan et al., 2020). Islam et al. (2015) suggested operating the farm machine in lengthwise to reduce turning events. Turning events increased the loss time of the machine.

Farm machinery cost represented the largest share of the whole operational price (Anderson, 1988; Buckmaster, 2003). Machinery cost was categorized as fixed cost parameter and variable costs parameter (Kepner et al., 1982; Hunt, 2001; William, 2005). Fixed cost follows irrespective of the machine utilization, and the operational cost differs with the machine usage. Fixed costs involved interest on investment, taxes, depreciation, insurance, every year repair and renovation and shelter costs of the machine. The fixed cost of the harvester is the most noteworthy machines cost, involving 40% of the total harvesting cost (Isaac et al., 2006). Variable costs of the harvester comprised rental charge, labor wage, oil & fuel costs, and repair and maintenance costs. The fuel cost represented the major share of variable costs. However, repair and maintenance cost increases over time. Alam et al. (2018) mentioned that the reaping cost of different types of reaper diminishes with the expansion in yearly harvesting land area coverage. The opportunity of using combine harvester is seasonal, i.e. only a few weeks per year. Spokas and Steponavicius (2011) recommended that harvesters have to provide the maximum feasible overall performance with the minimal feasible working costs. The harvesting cost of combine harvester differs with the initial investment on the purchase price, age, work rate, annual use, fuel and oil prices, spare parts and labor wages. The purchasing cost immensely affects the break-even point as opposed to the custom hiring cost and variable cost (Yousif and Babiker, 2018). Fixed cost, variable cost, and total operating cost of machine can be determined on the basis of per unit area, hourly, or yearly. Subsequently, a specific least measure of work ought to be accessible to justify the purchase of a machine. A few research global have assessed operating cost for a variety of harvesting techniques with a range of conditions and estimation approach (Sharanakumar et al., 2011; Soucek and Blazej 2012; Yousif and El-Awad 2012; Hossain et al., 2015; Masek et al., 2015). Investment in a harvester involves enormous assets, which influences benefit-cost ratio, and consequently farm gainfulness over the long haul.

There is a necessity to find out appropriate land size or plot length for SIFANG model combine harvester to minimize harvesting cost and conserve energy. But, no study has been reported considering the factors affecting field capacity with harvesting cost of combine harvester. Therefore, the current research used to be undertaken to assess the field overall performance (field capacity, field efficiency, time distribution and cost of harvesting) of the combine harvester with different land sizes in haor regions of Bangladesh. The outcome of the research would offer smallholder farmers to point out advanced planning and management in operating the combine harvester.

II. MATERIALS AND METHODS

A. Experimental location and period

This research was performed at Mithamain Upazila of Kishorganj district during Boro rice harvesting season, 2020 (Figure 1). Soft and muddy land area with a water top of 25 mm usually prevailed in the haor basin during the rice harvesting operation.

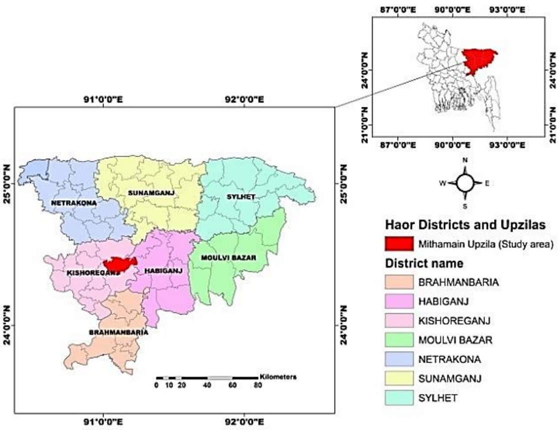

Figure 1: The study location of combine harvester

B. Technical specifications of the combine harvester

Sifang mini combine harvester (Model 4LZ-1.5) was used for rice harvesting from 16 March to 10 May 2020 (Figure 2). The technical specifications of the combine harvester are given in Table 1.

Table 1: Technical specifications of the combine harvester

Items	Specification
Type	Mini Harvester
Usage	Grain Harvester
Brand	Sifang
Model	4LZ-1.5
Country of origin	China
Material	Steel and rubber
Max power, kW	20
Rated speed, rpm	2200
Total weight, kg	1380
Drive Type	Gear Drive
Dimension(L*W*H), mm	4120*1700*1900
Tracking tire	Full track
Fuel	Diesel
Fuel tank holding capacity, l	12
Fuel intake, kg/hm²	≤22
Rated feed capacity, kg s^{-1}	1.5

Rated cutting width, mm	1360
Ground clearance, mm	200
Ground pressure, kpa	22
Grain tank holding capacity, kg	200
Paddy unloading discharge rate, kg s^{-1}	1.5 kg/s
Working width, m	1.5
Worker, person	1

Figure 2: Field operation of Sifang combine harvester.

C. Performances of combine harvester during field operation

The overall performance of combine harvester contains operational speed, theoretical field capacity, effective field capacity, field efficiency, working period and fuel utilization. Field efficiency is the percentage of effective field capacity and theoretical field capacity of combine harvester (Hunt, 2001).

$$\text{Theoretical field capacity, (ha h}^{-1}) = \frac{\text{Total area harvested (ha)}}{\text{Effective operation time(h)}} \quad (1)$$

$$\text{Effective field capacity (ha h}^{-1}) = \frac{\text{Total area harvested (ha)}}{\text{Total operation time (h)}} \quad (2)$$

$$\text{Field efficiency, \%} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100 \quad (3)$$

The fuel utilization was measured by means of refilling the diesel container of combine harvester again to its full limit after the harvesting process utilizing a measuring container. Time data were recorded utilizing advanced stopwatch which incorporated the actual harvesting operational time, turning time, and additional time. The average time is determined considering the total time value for all farms and the total number of farms. The forward speed of harvesting operation was once obtained through recording time taken to harvest every line with the aid of utilizing a stopwatch and measured the distance of line by utilizing a measuring tape; the average speed of harvesting operation used to be acquired through summation speed for all lines and divided by way of the number of lines.

D. Financial feasibility assessment of combine harvester

Costs in a number of segments of paddy harvesting operation (mechanical and traditional methods) were categorized into two items, fixed cost items and variable cost items. The operating cost of the combine harvester was calculated comprising the fixed cost and variable cost items (Equ. 4).

$$AC = FC + VC \quad (4)$$

Where,

AC = yearly operating cost, Tk yr^{-1}
FC = yearly fixed cost, Tk yr^{-1}
VC= variable cost, Tk yr^{-1}

Fixed cost (FC) is a component of the purchase price, interest rate and working life of the combine harvester and determined dependent on capital consumption (CC) method. A capital recovery factor (CRF) was utilized to consolidate the overall depreciation and interest variations into a sequence of equivalent yearly installments at compound interest. The capital recovery factor is frequently interpreted because the quantity of equivalent installments to be obtained for n years such the entire existing value of all these equivalent installments is equivalent to an installment of one taka at existing if the rate of interest is i. This installment is utilized to assess the capital consumption for farm machine (Hunt, 2001).

$$CC = (P - S)\,CRF + S \times i \quad (5)$$

$$CRF = \frac{i(i+1)^n}{(1+i)^n - 1} \quad (6)$$

Where,

CC = capital consumption
P = purchase value, Tk

S = salvage value, Tk
CRF = capital recovery factor
i = interest rate, %
n = working life of machinery, yr

The variable cost (VC) of combine harvester performs by the price of oil and fuel, daily working time, labor cost, and repair and maintenance charge of the harvester. All costs are related with the utilization of harvester and fluctuate to an enormous degree in direct extent to working hours or days of utilization every year. Variable costs were measured using the following equation (Hunt, 2001).

$$VC = \frac{A}{C}\left[(R \& M) \times P + L\right] \qquad (7)$$

Where,

A = yearly harvesting area coverage, ha
C = effective field capacity of the combine harvester, ha h^{-1}
R &M = repair and maintenance charge, %
P = purchase value of the harvester, Tk
L = labor cost, Tk h^{-1}

The break-even point (BEP) is the second when there is no profit or loss. The all out expenses of the farm would be proportionate as a result of the gross pay. It is essential to explore the operating cost of the harvester ceaselessly. The fixed costs must be secured by the pay: the greater the fixed costs, the more it will take for the business to arrive at make back the initial investment and make a benefit. Subsequently, it is fundamental to downplay fixed expenses down level. The break-even point of the combine harvester was calculated using the following equation (8).

$$BEP = \frac{FC}{CR - VC} \qquad (8)$$

Where,

BEP = break-even point, ha yr^{-1}
FC = fixed cost, Tk yr^{-1}
VC = variable cost, Tk ha^{-1}
CR = custom hire rate, Tk ha^{-1}

Comments on the performance of combine harvester were recorded from the users and operators through a structured questionnaire. The comments were validated through KII (Key Informant Interviews). MS-Excel 2013 was used to analyze experimental data and presented in graphical and tabular form.

III. RESULTS AND DISCUSSION

A. Harvesting capacity to combine harvester concerning the land size

The size and shape of harvesting land affect the harvesting performance of the combine harvester. Figure 3 shows the field capacity of Sifang combine harvester concerning the land size. The results revealed that the harvesting capacity of combine harvester increased with the increase in the land size of the harvesting plot due to less turning events. Suha et al. (2019) mentioned that the field performance of the combine harvesters is essentially influenced by a lessening in the size and shape of the plot area. A comparative outcome was acquired by ASAE Standards (2009) and detected that the irregularly formed plots may cause a generous decrease in the field performance of the combine harvester. The size of the land should be at least 500 m^2 to operate the Sifang combine harvester having a cutting width of 1.5m at full capacity. The crop field should be selected based on the size of the land to get the highest field performance of combine harvester.

B. The field capacity to combine harvester concerning plot length

Figure 4 shows the field capacity of Sifang combine harvester to plot length. The field capacity to combine harvester varied with the length of the plot due to a decrease in turning events. The field capacity of the combine harvester increases with the increase in plot length of the farm. The lowest field capacity was observed for plot length 25m. Therefore, plot length should be more than 25 m for Sifang brand combine harvester having cutting width 1.5 m to operate the machine with a minimum turning event.

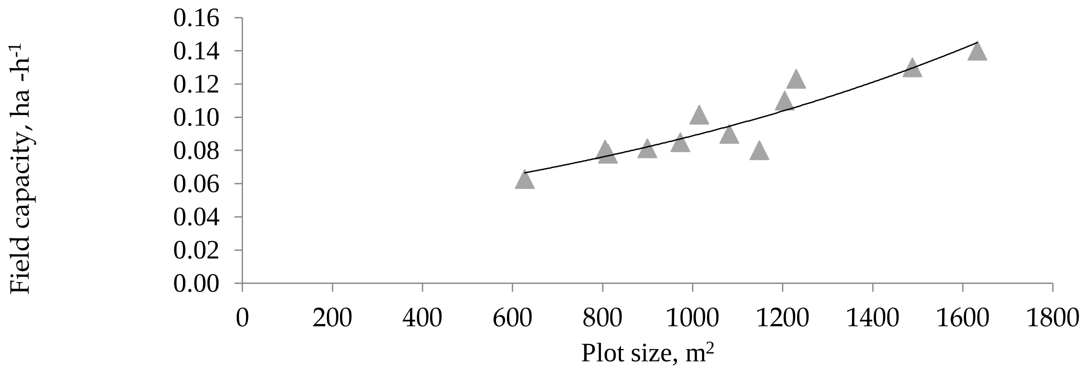

Figure 3: The field capacity of combine harvester for land size

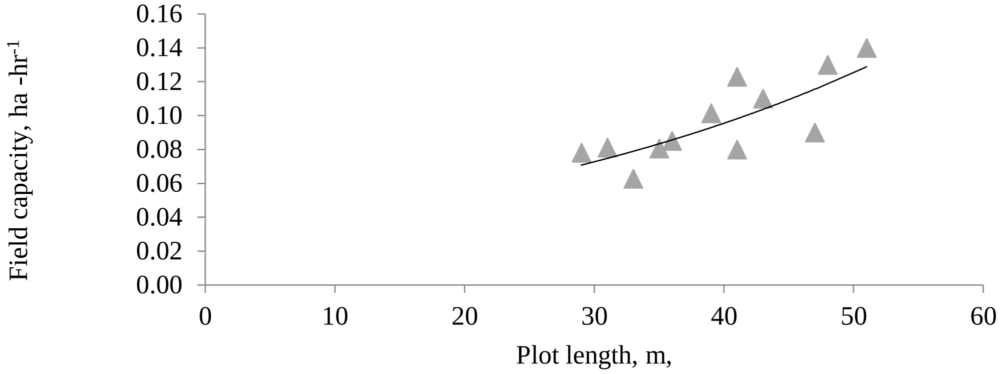

Figure 4: Field capacity of combine harvester concerning plot length

C. Field performance of combine harvesters in haor area

The results revealed that the operating speed of the combine harvester ranged from 1.40 to 1.90 km hr^{-1} during harvesting (Table 2). ASAE Standards (2009) stated that the operating speed of large and medium size combine harvester ranged from 3 to 6.5 km hr^{-1} during harvesting operation. The operating speed is low in *haor* areas due to low engine horsepower and smaller in size. The results showed that the theoretical and actual field capacity of the mini combine harvester was 0.19 and 0.11 ha hr^{-1}, respectively. The theoretical and effective field capacity was found 0.50 and 0.36 ha h^{-1}, respectively for full-feed and head-feed combine harvester (Alizadeh and Allameh, 2013). Muazu et al. (2014) stated that the least field capacity (0.67 ha h^{-1}) was obtained for the highest loss time (1.54 h) during harvesting operation of paddy. Therefore, the actual field capacity is low. The performance of the machine is not desirable in *haor* areas. Because harvesting season is abridged, farmers must harvest crops within a very short time to avoid natural disasters. The harvesting capacity of the Sifang combine harvester is relatively low. However, the advantage of Sifang size combine harvester is to work well in smaller sizes of fields.

Table 2: Field performance of combine harvester

Parameter	Value
Speed, km hr^{-1}	1.60±0.21
Lengthwise speed, km hr^{-1}	1.59±0.36
Widthwise speed, km hr^{-1}	1.38±0.47
Theoretical field capacity, ha hr^{-1}	0.19±0.03
Actual field capacity, ha hr^{-1}	0.11±0.01
Field efficiency, %	58±12.23
Fuel consumption, l ha^{-1}	17
Grain loss, %	2.13

D. Time distribution of combine harvester operation

Time distribution of combine harvester during harvesting operation is shown in Figure 5. The result showed that the combine harvester spent 45% in harvesting, 17% in turning and the remaining 38% of the total time in repairing, idle, work stop due to rain. Suha et al. (2019) reported that the huge estimate combine gatherer utilize 60.0% of the overall time within the actual harvesting of the rice whereas the remaining 40% of the overall time was utilized in turning, turning around and dumping activities. Conversely, the medium size combine harvester used 71.7% in harvesting and the remaining 28.3% of the entire time in turning, turning around and dumping activities. Muazu et al. (2014) expressed that 66% of the whole time was used in the real harvesting operation whereas the remaining 13% of the whole time was utilized in turning and reverse activities for a conventional combine harvester. Turning time of combine harvester is a loss factor activity that needs appropriate planning to make turns without reduces speed or utilizing additional movement to arrange the next row. Turning, reversing and dumping activities are unavoidable; the goal is to minimize the loss time, as they may add up to as much as 40% (Henrichsmeyer et al., 1995). This unavoidable time loss can be diminished with innovative practices.

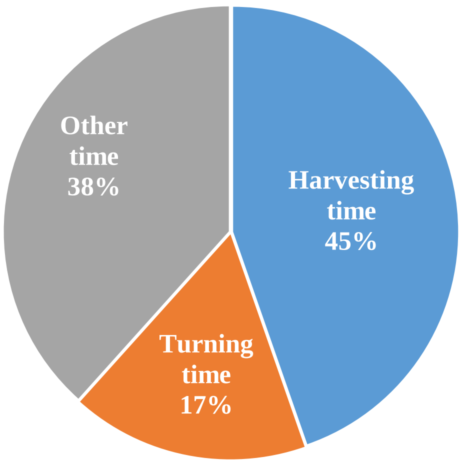

Figure 5: Time distribution in combine harvester operation

E. Repair and maintenance

The repair and maintenance is a significant factor in the assessment of a combine harvester. The harvester required some repair and maintenance at the time of harvesting operation, i.e. reel assembling, clogging in the threshing component due to moist and high densely crop feeding, crop lodging, hydraulic arrangement for movement of cutter bar and high noise and vibration due to single-cylinder engine.

F. Economic analysis

The hiring charge of a harvester for unit area is influenced by machine purchase price, fuel cost, labor wage, transport cost, yearly utilization and profit. The cost analysis of combine harvester for harvesting operation was estimated by considering relevant cost assumptions. Several assumptions were made during the study in order to estimate the fixed and variable cost. The total cost of harvesting was measured by including fixed cost and variable costs of the harvester. Fixed costs of combine harvester static in total however, decreases per hectare with the yearly utilization of the machine. Fixed cost parameters of combine harvester in terms of total fixed cost and operation costs are shown in Figure 6. The results were observed from fixed cost analysis; depreciation is the maximum cost item (49%) accompanied through interest (29%), repair and maintenance (R&M) cost. A similar trend was observed in the total operating costs of harvester. In total operation cost analysis, depreciation, interest, R&M cost were found 39, 23 and 17%, respectively. It was observed that the whole fixed cost assumption for combine harvester was 44% of the total operation cost. The value (44%) is lower compared to the other findings of Isaac et al. (2006); Yousif and Babiker (2018). They also confirmed that the fixed cost assumptions were the most significant segment of the overall operating cost of harvester.

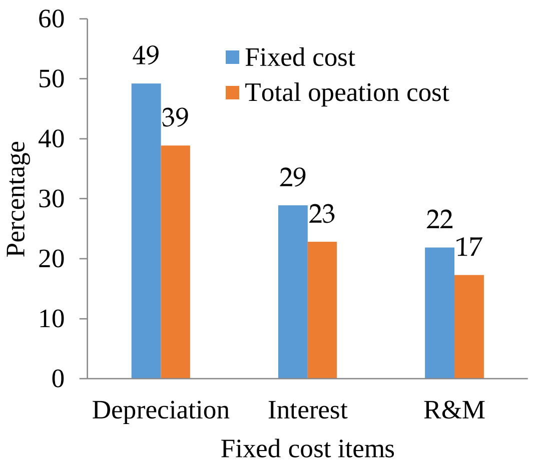

Figure 6: Fixed cost parameters of combine harvester in terms of total fixed and operation costs

Variable costs were focused on oil and fuel price, daily working time, labor cost, and repair and maintenance charge of combine harvester. Variable cost parameters of combine harvester in terms of total fixed and operation costs are shown in Figure 7. The results represented that the rental charge is the highest variable cost parameters (77%), followed by operator charge (14%) and fuel & oil cost (9%). The variable cost items revealed the similar trend in the total operation cost. However, Spokas and Steponavicius (2011) observed that the utilization of fuel influenced the overall operation cost of combine harvester and the amount of total variable cost parameter added up to 31.5% of the total operation cost.

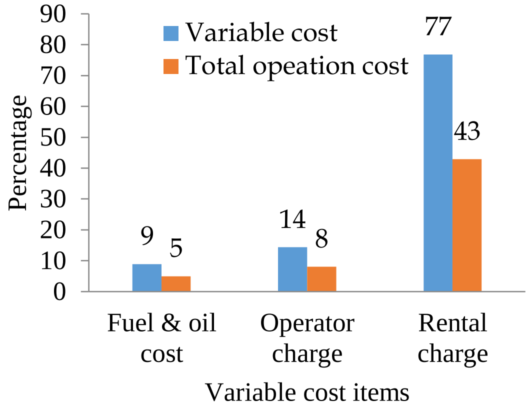

Figure 7: Variable cost parameters of combine harvester in terms of total fixed and operation costs

Figure 8 illustrates the break-even chart for mechanized harvesting using the Sifang combine harvester. The break-even area of mechanized harvesting using Sifang combine harvester would be 7.5 hectares of rice land to cover yearly fixed cost. The results showed that the total operating cost for paddy harvesting with combine harvester decreases with the increase in yearly harvesting land area coverage. The results also revealed that the combine harvester is profitable to the end users when the yearly harvesting area coverage exceeds the amount of rice land.

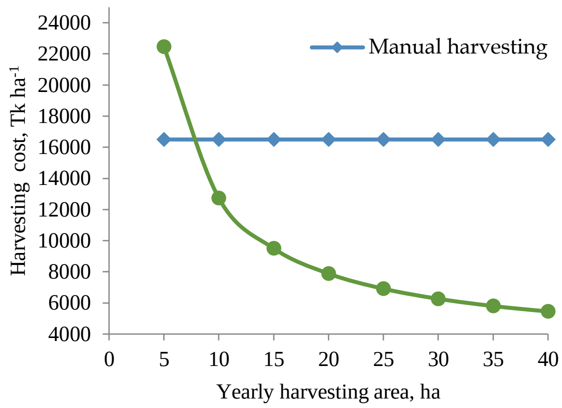

Figure 8: Break-even area to area coverage

G. Machine status during operation

The mechanical fault of the combine harvester during harvesting operation was summarized and presented in Table 3.

Table 3: Machine status during operation

Parameters	Comments
Header unit	Reel successfully gathered the crop.
Cutting unit	Cutter bar moves smoothly and successfully cut the crop. Any uncut plant was not found.
Conveying unit	Cut crop conveyed to the threshing drum by conveyer belt. Overfeeding clogged the conveying unit
Threshing unit	Grains were separated from panicle successfully
Cleaning unit	A cyclone separator cleaned grains. Cleaning was good.
Bagging unit	Grains were delivered directly to the bag.
Power transmission system	The gear mechanism is not the operator's friendly.
Vibration and noise	The vibration behaviors of many structures are more prominent. There is robust vibration at the header component of the harvester, which is prompted by the load and the street surface. Driver's comfort and working life of all frame reduces due to vibration and noise of cutting component. Nuts and bolts were loosened due to vibration. The operator did not feel comfortable due to the vibration of the machine. This uncomfortable level of vibration increases human drudgery, which severely affects to operate the combine harvester for an extended time during the paddy harvesting seasons.
Harvesting speed	Unable to increase the cutting speed. The machine is a little bit of slow motion. Increased speed creates clogging in the feeding of the conveyer belt. Over high speed makes too much vibration on the front header and affected the reel movement to increase header loss of paddy.

H. Operators' comments

Operators were asked to make comments on the following issues. The comments are summarized and given in Table 4.

Table 4: Operators' observations during the operation of combine harvester

Parameters	Observations
Operation	Strong vibration and noise. Operators' does not feel comfortable to operate the harvester. Seating arrangement helped the operator ease of operation
Straight movement	Faced no problem in a straight movement
Lowering and uplifting in the field	There is a problem in uplifting on higher ground
Driving on the road	There is no difficulty in moving on the road. However, turning in the road caused crawler damage.

I. Farmers' comments

Farmers were asked to express comments on the following issues. The comments are summarized and given in Table 5.

Table 5: Farmers' comments on the performance of combine harvester

Parameters	Comments
Grain cleaning	More than 95% of cleaned grain was obtained. Every farmer satisfied the grain cleaning
Grain damage	Farmers' did not find any significant amount of grain damage
Status of straw after harvesting	Straws were chopped after harvesting. Every farmer opined that they could keep straw for a long time after getting from a combine harvester
Grain collection	Grans are collected in a bag. Farmers showed satisfaction on grain collection through the bag
Threshing loss	Farmers find nominal unthreshed grain in the straw which is acceptable by the farmers
Harvesting capacity	Harvesting capacity is low. Farmers showed dissatisfaction

	with the harvesting capacity of Sifang combine harvester

J. Overall observations

Overall observation on the crop and land condition was recorded and presented in Table 6.

Table 6: Overall observations on the crop and land condition of harvested field

Parameters	**Comments**
Land condition	Sandy soil. The land is good. Water splashes in the field
Depth of mud, mm	30-40
Crop position	Standing
Inclination of crop	The percentage of inclined crops is about 80% with an angle of 70 degree
Crop density	Moderate to high density
Crop height, mm	840-950
Straw left in the field after harvesting, mm	90-140
Overall comments	Farmers showed satisfaction on the performance of Sifang combine harvester

IV. CONCLUSIONS

The performance parameters of Sifang combine harvester are found satisfactory. The result revealed that the harvester is suitable for operation in small sizes of harvesting fields. The size of the land should be at least 500 m^2 to operate the Sifang combine harvester having a cutting width of 1.5m at full capacity. The theoretical and actual field capacity of the mini combine harvester is 0.19 and 0.11 ha hr^{-1}, respectively. The combine harvester will be commercial to the farmers when the annual area coverage exceeds 7.5 hectors of land. This machine may be operated in small sizes of lands where bigger sizes are inaccessible. However, this harvester may be recommended for smallholder farmers in other areas over the country for mechanization of rice harvesting to assist future adoption of improved harvesting innovations.

ACKNOWLEDGMENTS

This research was performed as part of the project entitled "Strengthening Farm Machinery Research Activity for Mechanized Rice Cultivation project," Bangladesh Rice Research Institute, Gazipur.

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