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Custom Hiring Service of Reaper for Harvesting Paddy

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ABSTRACT

Paddy harvesting is labor and time intensive operation. There is an acute shortage of labor in pick paddy harvesting seasons in Bangladesh that promotes the growing market potential for providing hiring services of reaper by small entrepreneur to the farmers. Therefore, the study was conducted to determine the economic performance of Custom Hiring Service (CHS) of reaper for harvesting paddy in Bangladesh. Primary data were collected through field experiments and survey at *Dumuria*, *Wazirpur*, *Subarnachar* and *Kalapara* Upazilas of Khulna, Barisal, Noakhali and Patuakhali districts, respectively, of Bangladesh during six paddy harvesting seasons. Economic analyses for CHS of reaper were also carried out in the study. Operating costs were calculated and financial profitability was determined by four major financial parameters, namely, benefit-cost ratio (BCR), net present value (NPV), internal rate of return (IRR) and payback period. The BCR of the reaper was found 2.04 which indicates that the reaper is highly profitable for the hiring service. Considering 10% discount rate, NPV of the reaper was found BDT 426106 which indicates that reaper can be considered as financially viable. The estimated IRR of the reaper was found 91%, which is far greater than the bank rate of interest (9%). The payback period of the reaper was found 1.06 years. The break-even use of the reaper was found 14.79 ha per year. Major indicators in the analysis show that the investment on a reaper is highly profitable for custom hiring service. This analysis also supports for growing custom hiring service market of reaper in rural Bangladesh.

Introduction

Agriculture is one of the important production sectors of the economy of Bangladesh and contributes about 10.98% to the total Gross Domestic Product (GDP). This sector also accommodates around 40.6% (in 2016-17) of the labor force (BBS, 2018). Steady GDP growth rate of Bangladesh is also depends on the performance of the agriculture sector beside other sectors. The total population of Bangladesh is estimated as 162.7 million (BBS, 2018). The population of Bangladesh is still growing and is expected to reach 200 million by 2050 (UN, 2012). On the other hand, the amount of cultivable land per capita is decreasing due to various non-agricultural activities such as increased industrialization and urbanization. Zhang *et al.* (2014) showed that a progressive shrinking of rural labor availability, as workers migrate to cities or abroad to engage in more remunerative employment, particularly in the garments and construction sectors. Projections also indicate that rice and wheat production will need to increase by 0.4 and 2.17% year^{-1}, to keep pace with the additional two million population added annually (Mainuddin and Kirby, 2015). However, the two conditions cannot be fulfilled due to the shortage of manpower at that particular time. At the same time, there is little scope to extend the agricultural land frontier: crop land availability in Bangladesh has declined by 68,760 ha year^{-1} (0.73%) since 1976 (Hasan *et al.,* 2013). In other words, Bangladesh needs to produce more food from the same land, while at the same time easing farm labor requirements resulting from the country's increasingly profitable alternative forms of employment (Zhang *et al.,* 2014).

During the harvesting season the weather condition may change abruptly such as heavy rain, storm, sudden flood, etc. In addition to this, labor demand becomes very high at the time of peak harvesting season (Chand and Kumer, 2002; Leonce and Saraswat, 2015). Acute labor shortages

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at harvesting time cause delays in clearing fields leading to high grain and straw losses (Kiran *et al.,* 2017). Due to unavailability of mechanical harvesting, a significant amount of field losses of rice every year has been occurred due to natural calamities and shortage of time during the harvesting period (Noby *et. al.* 2018). For harvesting and threshing of paddy, the demand of machine is drastically increased in Bangladesh. But, farmers do not have specific information about these machines that will be reasonable for them for the purpose of harvesting. Selection of proper harvesting method and equipment depends upon a number of factors such as farm size, farmers' constraints, crop constraint, availability of labor, and time limitations (Ojha and Michael, 2008). Therefore, farmers need a proper guideline to choose the cost effective machine, so that the production cost of rice can be minimized and profit can be increased. As the price of rice is low therefore, minimization of cultivation cost is very much important for farmers. The government has given top priority to increasing the availability of food in the country, while the paddy land is not expanding (MoA, 2013). One way to increase the production is to minimize the yield gap between research and farmers level. Another important task is to minimize postharvest losses. The introduction of appropriate machinery is one of the major factors for reducing time, labor requirements, production cost and also to help introducing another crop in between successive two crops (Zami *et al.,* 2014).

There is an opportunity to use machines through custom hire service (CHS) to avoid the initial investment issue. In land and capital constrained rural Bangladesh, owners of agricultural machinery also tend to work as service providers (e.g. providing mechanized land preparation and irrigation) on a fee-per-service basis to other farmers. As a result, even the smallest farm households can usually access relatively affordable machinery services through custom hiring services (Justice and Biggs, 2013; IDE, 2012). Most private equipment owners started providing the custom hiring services (CHS) of various machines to the farmers at appropriate times and at reasonable rates, which ultimately reduce the fixed cost of farm operations and reduce the burden of capital investments or credit from the bank. The operation of the custom hiring services (CHS) in agricultural mechanization is economically viable. The cost of farm operations could be reduced to almost half by custom hiring of the machining services (Sidhu, R.S., 2012). Local machinery service providers are doing business in the farmers' field as custom hire services (CHS) basis, but the numbers of these service providers are not adequate (Hossain *et al.,* 2014). The service provider model addresses the constraints of smallholder farmers on fragmented holdings while overcoming the barriers to reaching large numbers of farmers. Previous studies (Hasan *et al.,* 2019) indicated that reaper is technically suitable for Bangladesh context. This study has been undertaken to determine the economic parameters of reaper for knowing the feasibility and adoption of custom hire service (CHS) of the reaper.

Materials and Methods

Selection of harvesting machine

Reaper was used in the study. Model of selected reaper Vikyno AR 120 was used for harvesting of paddy at the experimental sites. The reaper was imported from Vietnam by ACI Motors Ltd. Technical specifications are presented in Table 1 and harvesting operation is shown in Fig.1.

Figure 1. Paddy harvesting using a reaper

Table 1. Specifications of a reaper

Model	Vikyno AR 120
Dimension (L×W×H) mm	2000×1400×1100
Weight (kg)	126
Header Width (mm)	1200
Forward Speed (km/hr)	2~3.6
Capacity (ha/hr)	0.20~0.40
Fuel Consumption (L/hr)	0.7~0.9
Engine Power (hp)	6.5
Engine Type	Petrol Engine
Tyre Type	Tubeless
Country of origin	Vietnum

Experimental locations

Experiments on both mechanical and manual harvesting of paddy using reaper and the traditional manual system were conducted at *Dumuria*, *Wazirpur*, *Subarnachar* and *Kalapara* Upazilas of Khulna, Barisal, Noakhali and Patuakhali districts, respectively of the Southern Delta region of Bangladesh as shown in Fig.2. The main source of the income of the farmers in all selected locations is agriculture. Two villages in each upazila were selected for this study.

***Dumuria** Upazila*
(Located in between 22°43' and 22°56' N latitudes and in between 90°01' and 90°18' E longitudes)

***Subarnachar** Upazila*
(Located in between 22°28' and 22°44' N latitudes and in between 90°59' and 91°20' E longitudes)

***Wazirpur** Upazila*
(Located in between 22°43' and 22°56' N latitudes and in between 90°01' and 90°18' E longitudes)

***Kalapara** Upazila*
(Located in between 21°48' and 22°05' N latitudes and in between 90°05' and 90°20' E longitudes)

Figure 2. Experimental locations in Bangladesh map

Data collection

Economic analysis is the most important part to develop an appropriate business model for custom hire services (CHS) of agricultural machinery. For appropriate economic analysis, primary data were collected through a field experiment during harvesting of *Aman*-2016, *Boro*-2017, *Aman*-2017, *Boro*-2018, *Aman*-2018 and *Boro*-2019 paddy in the selected locations and surveyed by filling up pre-tested questionnaire in the same locations.

Cost estimation

The economic profitability of selected harvesting technology like reaper in this study was determined based on cost analysis. The cost analysis considered the fixed and variable costs of the machine.

Fixed cost

Fixed costs are fixed in total, but decline per ha, as the annual use of the machine is increased (Barnard & Nix, 1979). Fixed cost comprises those costs, which must bear regardless of the machine is used. These costs include i) depreciation cost, ii) interest in investment and iii) taxes, shelter and insurance.

Depreciation cost

Depreciation is the reduction in the value of the machine as a result of the use (wear and tear) and obsolescence (availability of newer and better model). In calculation of fixed cost, sinking-fund depreciation is assumed and was calculated by the following equation, (Hunt, 2001).

$$D = \left[(P-S)\left\{\frac{(1+i)^{L}-(1+i)^{n}}{(1+i)^{L}-1}\right\}+S\right]-\left[(P-S)\left\{\frac{(1+i)^{L}-(1+i)^{n+1}}{(1+i)^{L}-1}\right\}+S\right] \quad \text{.....(i)}$$

where, D = depreciation, BDT/yr; P = purchase price, BDT; S = salvage value (10% of P), BDT; L= Effective working life of the machine, yr; n = age of the machine in years at the beginning of the year, yr; i = annual bank interest rate, decimal.

Interest on investment

The interest on investment in reaper is included in the fixed cost estimation. The following equation was used for the calculation of interest on investment (Hunt, 2001):

Interest on investment,

$$I = \frac{P+S}{2} i$$

(BDT/yr).....(ii)

where, *P* = Purchase price, BDT; *S* = Re-sale value, BDT; *i* = annual interest rate.

Taxes, Shelter and Insurance (STI)

In the calculation shelter, tax and insurance were considered for calculating fixed cost of the harvesting machine (Hunt, 2001).

TI= 2.5% of P.....(iii)

Variable cost

The variable cost of a reaper is reflected in the cost of fuel, lubrication, daily service, power and labor. These costs increase with increasing the use of the machine, and vary to a large extent in direct proportion to hours or days of use per year. The cost of operator/labour was calculated at the labor rate in BDT/hr. The fuel and oil costs were estimated from consumption rates and multiplied by their respective prices. Fuel cost, oil cost,

labor cost and repair & maintenance cost were determined using the following equations (Hunt, 2001).

$$\text{Fuel cost, F (BDT/ha)} = \frac{\text{Fuel consumed (L/day)} \times \text{Price (BDT/L)}}{\text{Area covered (ha/day)}}$$

…….. (iv)

Oil cost, O (BDT/ha) = 15% of Fuel cost, *F* ……. (v)

$$\text{Lobor cost, L (BDT/ha)} = \frac{\text{Sum of wages of labor (BDT/day)}}{\text{Area covered (ha/day)}}$$ …. (vi)

Repair and maintenance cost, R&M (BDT/ha)=0.025 % of purchase price……..(vii)

M_c= Miscellaneous cost, BDT/ha

Total variable cost = (F + O + L + R & M + M_c) BDT/ha ……. (viii)

Total cost of harvesting (BDT/ha) = Fixed cost (BDT/ha) + Variable cost (BDT/ha) .....(ix)

Operating cost

White *et al.* (1989) mentioned that operating costs are recurring costs that are necessary to operate and maintain a machine during its useful life. Mainly operating costs of reaper were divided into fixed costs and variable costs. The following equation was used to operating cost calculation, considering the sum of the fixed and variable costs.

Operating cost (BDT/ha), OC = FC + VC……..(x)

Sinking fund annual payment (SFP) or payment for replacement

Replacement of machine by new one is essential because, beyond economic life, it is no longer being useful for operating in the field. Performance of a new machine is significantly superior and it makes the old machine obsolete. Anticipated costs of operating the old machine exceed those of a replaced machine. Uniform annual payments to a fund are of such a size that by the end of the life of the machine the funds and their interest have accumulated to an amount that will purchase another equivalent machine. The following equation was used for the calculation of sinking fund annual payment (SFP) (Hunt, 2001):

Sinking fund annual payment,

$$\text{SFP} = (\text{P} - \text{S}) \times \frac{\text{i}}{(1+\text{i})^{\text{L}} - 1} \times 100$$ ……..(xi)

where, P = Purchase price of the reaper, BDT; S = Salvage value, BDT; L = Life of the machine, yr. and i = Interest rate, decimal.

Rent-out charge

An entrepreneur can estimate the reaper rent-out charge from the following expression:

Rent-out charge = Operating cost + SFP + Estimated profit……..(xii)

The profit of the entrepreneur depends on the socioeconomic condition of the reaper user as well as country. In this study, the profit of the entrepreneur was estimated on the basis of middle-class family income in Bangladesh.

Economic analyses for custom hire services

The project appraisal technique has been followed to find out the profitability of reaper from owners of view. There are four alternative discounting measures are commonly applied for project appraisal (Gittinger, 1982). These measures are: i) Payback period, ii) Benefit-cost ratio (BCR), iii) Net Present Value (NPV) and iv) Internal Rate of Return (IRR). However, this appraisal is based on four assumptions, which are (i) All the devices are purchased with cash; (ii) Operation technology is remaining unchanged throughout the project life; (iii) Prices of all inputs and outputs are given and constant throughout the project life; and (iv) Twelve percent interest rate has been assumed for calculating BCR and NPV.

Payback period

Payback refers to the time period within which the costs of investment can be covered by revenues. The payback period is computed by applying the following formula:

Payback period = Investment (total initial, BDT)/ Net benefit (BDT/yr)……(xiii)

Benefit-Cost ratio

The benefit cost ratio is an important factor to measure the profitability of using reaper. If the benefit cost ratio (BCR) ratio is greater than unity, then it will be economically viable. BCR is calculated by using the following formula:

BCR = ∑ Present worth of Benefits (PWB)/ ∑ Present worth of costs (PWC) ……..(xiv)

Net present value (NPV)

Net present value (NPV) is a scientific method of calculating the present value of cash flows, both inflows and outflows of an investment proposal, using a discount rate and subtracting the present value of outflows to get the net present value. Net present value (NPV) is calculated by using the following formula:

Net present value (NPV) = ∑ Present worth of Benefits (PWB) -∑ Present worth of costs (PWC)……(xv)

Internal rate of return (IRR)

Internal rate of return (IRR) is called discount cash flow (DCF) yield or DCF return on investment or effective rate of interest method or marginal efficiency of capital. The IRR is the value of discount factor when the NPV is zero. The internal rate of return is a rate in quantity. It is an indicator of the efficiency, quality and/or yield of an investment. IRR is computed with the help of this formula (Gittinger, 1982):

IRR = Lower discount rate + (Difference between the discount rates) × {Present worth of cash flow at lower discount rate/ (Sum of the present worth the of cash flows at the two discount rates, signs ignored)} ……(xvi)

Break-even use

The break-even analysis is a useful tool to study the relationship between operating costs and returns. It is an intersection point at which neither profit nor loss is occurred. Above which the machine use can be considered as net gain (Gittinger, 1982). The break-even use of a reaper depends on its capacity of harvesting, power requirement, labor requirement and other charges.

Break even use, ha/yr = Annual fixed cost, BDT/yr/ (Return, BDT/ha –Variable cost, BDT/ha)…….(xvii)

Results and Discussion

Operating cost of a reaper

From field experiment and data analysis, salient features of reaper custom-hire entrepreneurship are shown in Table 2. The operating cost of a reaper was found BDT 1932 per ha which is the sum of fixed and variable costs. Fixed cost mainly depends on the purchase price of the reaper and variable cost depends on the cost of fuel, lubrication, daily service, power and labor cost. The fixed cost of the reaper was found BDT 757 per ha, on the other hand, variable cost was found BDT 1932 per ha.

Financial analyses of reaper for custom hire services

The business of reaper is seasonal. In a year, it can be used at least 40 days or 55.20 ha harvesting. The reaper machine can be used based on the average working capacity of the machine. The estimated working life of a reaper is 5 years or at least 10 seasons. During operation of the reaper, one (01) operator and two (02) labors are required for preparing the paddy field. Major cost items of reaper operation business in custom hire service are presented in the following Table 3.

PP, BCR, NPV and IRR

Economic analysis for a custom hire service of reaper was carried out from the viewpoint of reaper owner. Discounted measures of project were used for financial analysis since undiscounted measures of project worth has been quite unable to be taken into consideration the timing of benefits and costs. The results supported that investment on reaper is highly profitable. The result in Table 3 shows that the payback period (PP) of the reaper was determined as 1.06 years with an initial investment size of BDT 165,000 that means the stream of cash proceeds produced by an investment to equal the initial expenditure incurred after 1.06 years. The BCR for a reaper is 2.04 which is higher than unity. Considering 10% discount rate, the NPV of the reaper in existing condition is BDT 426106. The NPV of reaper indicates that reaper is considered financially sound and the project is said financially viable because the estimated IRR for reaper was 91% which is far greater than the bank interest rate. It indicates that investing on a reaper is highly profitable and highly suitable for the development of custom-hire entrepreneur of the reaper.

Sinking fund annual payment (SFP)

Based on the economic life of the reaper, an entrepreneur needs to save or deposit BDT 24813 per year in a bank account as shown in Table 3, so that he can buy a new reaper when the economic life of the old reaper expires for harvesting operations. Replacement of reaper by new one is essential because, beyond economic life, it is no longer being useful for operating in the field. The accident may have damage the reaper beyond repair. Performance of a new reaper is significantly superior and it makes the old reaper obsolete. Anticipated costs of operating the old reaper exceed those of a replaced reaper. Therefore, a reaper entrepreneur has to save money to buy the new one. Uniform annual payments to a fund are of such a size that by the end of the economic life of the machine the funds and their interest have accumulated to an amount that will purchase another equivalent machine.

Rent-out charge

Rent-out charge must be found out to sustain the entrepreneurship or custom hire service (CHS) business. Based on the field data and estimation of cost items with appropriate equations and assumptions, the rent-out charge of reaper for the harvesting operation was estimated as BDT 4000 per ha (shown in Table 3) in which operating cost, profit and SFP are included.

Break-even use

The break-even use of the reaper was found about to be 14.79 ha/yr as shown in Fig.3. It indicates that a reaper should operate above 14.79 ha/yr to have profited. The reaper will run on fully profit basis if it can be used more than 14.79 ha/yr.

Table 2. Salient features for a reaper operation business in custom hire services

Items	Unit*	Amount
Purchase price of Reaper (P)	BDT	1,65,000
Salvage value (S) (10% of P)	BDT	16,500
Working life (L)	yr	10
Average working hours per year	hr/yr	240
Field capacity of reaper	ha/hr	0.23
Average working hectare per year	ha/yr	55.20
Annual fixed cost	BDT/yr	41773
Fixed cost per hour	BDT/hr	174.05
A. Fixed cost per hectare	BDT/ha	757
Fuel cost per hour	BDT/hr	68.7
Lubricant cost per hour	BDT/hr	10.31
Repair and maintenance cost (0.025% of P)	BDT/hr	41.25
Repair and maintenance cost per year	BDT/yr	9900
Labor cost per hour	BDT/hr	50.00
Operator cost per hour	BDT/hr	75.00
Variable cost per hour	BDT/hr	270.28
Annual variable cost	BDT/yr	64868
B. Variable cost per hectare	BDT/ha	1175
Operating cost of a reaper (A+B)	BDT/ha	1932

* Unit.: Average daily working=6h; Yearly use=40 day and Price of petrol=BDT 65 per litre

Table 3. Financial features of reaper operation business

Items	Unit*	Amount
Purchasing price of reaper (P)	BDT	1,65,000
Salvage value of reaper (S) (10% of P)	BDT	16,500
Operating cost of reaper	BDT/ha	1932
Estimated profit	BDT/ha	1619
Rent out charge of reaper	BDT/ha	4000
Payback period (PP)	Years	1.06
Benefit-cost ratio (BCR)	-	2.04
Net present value (NPV) at 10% DF	BDT	426106
Internal rate of return (IRR)	%	91%
Sinking fund payment (SFP)	BDT/yr	24813
Breakeven use	ha/yr	14.79

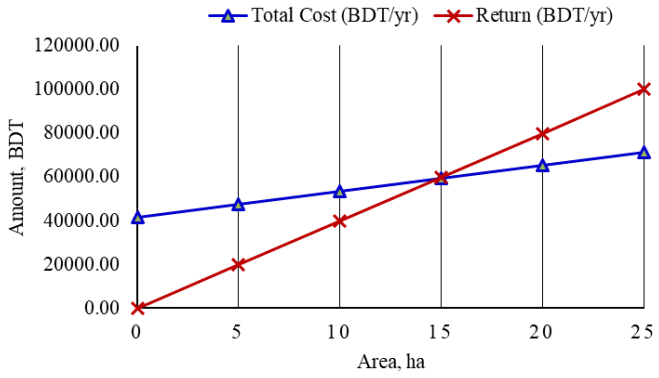

Figure 3. Break-even use of reaper

Table 4. NPV, BCR, IRR and Payback period Calculation at DF 10%

Year	Fixed cost (BDT)	Variable cost (BDT/yr)	Gross return	Cash flow (BDT)	Present value of cash flow	Present value of cost	Present value of Benefit	Balance (BDT)
0	165000			-165000	-165000	165000	0	-165000
1	0	64,868	220800	155932	141757	58971	200727	-9068
2	0	64,868	220800	155932	128869	53610	182479	146864
3	0	64,868	220800	155932	117154	48736	165891	302797
4	0	64,868	220800	155932	106504	44305	150809	458729
5	0	64,868	220800	155932	96822	40278	137100	614661

NPV= BDT 426106; BCR = 2.04; IRR= 91% and Payback period = 1.06 yr

Table 5. Project worth evaluation

Items	Value	Remarks
Payback period (PBP)	1.06 yr	If less than economic life (1.06 yr < 5 yrs) **Accept**
Break-even use (BEU)	14.79 ha/yr	If less than service area (14.79 ha/yr < 55.20 ha/yr) **Accept**
Benefit-cost ratio (BCR)	2.04	If greater than 1.0 (2.04 > 1.0) **Accept**
Internal rate of return (IRR)	91%	If greater than prevailing interest rate (91% > 12%) **Accept**

For getting break-even use, rent-out charge was considered BDT 4000 per ha on the basis of field survey and the total cost was estimated from the summation of annual fixed cost and variable cost. Annual fixed cost will not vary, but the total variable cost will vary along with the annual area coverage.

Project worth evaluation

Discounted measures of project were used for financial analysis since undiscounted measures of project worth has been quite unable to be taken into consideration the timing of benefits and costs (Table 4). Also, project worth evaluations are shown in Table 5. The results revealed that investment on a reaper is profitable for an entrepreneur in custom hire business operation. The result in Table 5 reveals that the PBP of reaper is 1.06 years along with machine working life five years. It means that machine owner will get profit after 1.06 years and until five years. The BEU of the reaper is 14.79 ha/yr along with annual machine working capacity is 55.20 ha/yr. It means that machine owner will get profit after using more than 14.79 ha/yr considering five years working life and annual possible working capacity is 55.20 ha/yr. The BCR of the reaper is 2.04 that is higher than unity. Custom higher business of any farm machine will be profitable if BCR of the machine is higher than unity. The estimated IRR is 91% which is far greater than the bank interest rate. It indicates that investing on the reaper is profitable and suitable for development of custom-hire service business.

Conclusion

The operating cost of reaper is important economic aspects of reaper custom hire entrepreneurship. The results of payback period (PBP), benefit cost ratio (BCR), net present value (NPV) and internal rate of return (IRR) indicated that investing on a reaper is highly profitable and highly suitable for development of custom-hire entrepreneur. The reaper is found suitable in terms of financial performance over manual harvesting of paddy, and recommended for development of reaper custom-hire service (CHS) entrepreneurship to avoid initial investment as machine user. To meet up the labor crisis in the peak harvesting period and reduce harvesting cost, human drudgery and labor involvement, using reaper for paddy harvesting could be an appropriate solution. Based on the analyses of the collected data, it can be recommended that an individual innovative farmer, entrepreneur as well organized farmers' groups can invest their shared capital in providing services to the members of the group and other neighboring farmers.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Barnard, C. S., and Nix, J. S. 1979. Farm planning and control (2nd edition.). London-New York-Melbourne: Cambridge University Press, Cambridge, United Kingdom.

BBS, 2018. Statistical Pocket book of Bangladesh. Bangladesh Bureau of statistics. Ministry of Planning, Bangladesh.

Chand, R. and Kumar, P. 2002. Long-term changes in course cereal consumption in India. Indian Journal of Agricultural Economics,57(3).

Gittinger, J.P. 1982. Economic analysis of agricultural projects. Jhon Hopkins University Press, Baltimore.

Hasan, M. K., Ali, M. R., Saha, C. K., Alam M. M. and Hossain, M. M. 2019**.** Assessment of Paddy Harvesting Practices in Southern Delta Region of Bangladesh. *Progressive Agriculture*. 30(l): 57-64. https://doi.org/10.3329/pa.v30i0.41558

Hasan, M. N. M., Hossain, S. M., Islam, R. M. and Bari, M. A. 2013. Trends in the Availability of Agricultural Land in Bangladesh. Soil Resource Development Institute (SERDI), Ministry of Agriculture, Bangladesh, Dhaka. Available from URL: http://www.nfpcsp.org/agridrupal/sites/default/files/Trends-in-the-availability-ofagricultural-land-in-Bangladesh-SRDI-Supported-by-NFPCSP-FAO.pdf

Hossain, M. I., Siddiqui, M. N. A., Panaullah, G. M., Duxbury, J. M. and Lauren, J. G. 2014. Raised beds: A resource conserving technology for improved crop production in Bangladesh. A booklet under Cornell University-Food for progress programme in Bangladesh.

Hunt, D. 2001. Farm power and machinery management (No. Ed. 10). Iowa state university press, U.S.A.

IDE (International Development Enterprises) 2012. Commercialization of Selected Agriculture Machineries in Bangladesh. Dhaka: International Development Enterprises (IDE). Available from URL:http://repository.cimmyt.org/xmlui/bitstream/handle/10883/3394/98527.pdf

Justice, S. and Biggs, S. 2013. Rural and agricultural mechanization in Bangladesh and Nepal: status, processes and outcomes. In: Kienzle J., Ashburner J.E., Sims B.G., editors. Mechanization for Rural Development: a Review of Patterns and Progress from Around the World. Food and Agriculture Organization of the United Nations (UNFAO); Rome. pp. 67–98.

Kiran, I. K. M., Awal, M. A. and Ali, M. R. 2017. Development and performance evaluation of a battery operated small-scale reaper. Agricultural Engineering International: CIGR Journal, 19(2): 217–223.

Leonce, H. and Saraswat, D. C. 2015. Comparative Study of Performance and Economics of Self Propelled Combine Harvester with Other Harvesting and Threshing Methods on Paddy Rice. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS), 6(6): 377

Mainuddin, M. and Kirby, M. 2015. National food security in Bangladesh to 2050. Food Secure. 7(3): 633-646. https://doi.org/10.1007/s12571-015-0465-6

MoA (Ministry of Agriculture). 2013. http://www.moa.gov.bd/

Noby, M. M., Hasan, M. K., Ali, M. R., Saha, C. K., Alam, M. M. and Hossain, M. M. 2018. Performance evaluation of modified BAU self-propelled reaper for paddy. Journal of Bangladesh Agricultural University,16(2): 171-177. https://doi.org/10.3329/jbau.v16i2.37956

Ojha, T. P. and Michael, A. M. 2008. Principles ofAgricultural Engineering. Jain Brothers, New Delhi.

Sidhu, R. S. and Kamal, V. 2012. Improving Economic Viability of Farming: A Study of Cooperative Agro Machinery Service Centres in Punjab. Agricultural Economics Research Review. Vol. 25: 427-434.

UN 2012. World Population Prospects. Available from http://www.un.org/en/development/desa/publications/world-population-prospects-the-2012-revision.html

White, J. A., Agee, M. H. and Case, K. E. 1989. Principles of Engineering Economic Analysis (3rd ed.). London-New York-Melbourne: John Wiley & Sons, Incorporated.

Zami, M. A., Hossain, M. A., Sayed, M. A., Biswas, B. K. and Hossain, M. A. 2014. Performance Evaluation of the BRRI Reaper and Chinese Reaper Compared to Manual Harvesting of Rice (*Oryza sativa* L.). The Agriculturists 12(2):142-150. https://doi.org/10.3329/agric.v12i2.21743

Zhang, X., Rashid, S., Ahmad, K., and Ahmed, A. 2014. Escalation of real wages in Bangladesh: is it the beginning of structural transformation? World Dev. 64, 273-285. https://doi.org/10.1016/j.worlddev.2014.06.015