COMPARATIVE FIELD PERFORMANCE OF DIFFERENT RICE HARVESTING METHODS IN DINAJPUR

A THESIS

BY

MD. MASUD RANA

Registration No: 1805125

Session: 2018-2019

Semester: January-June, 2019

MASTER OF SCIENCE (MS)

IN

FARM POWER AND MACHINERY

DEPARTMENT OF AGRICULTURAL AND INDUSTRIAL ENGINEERING

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JUNE, 2019

Dedicated

To

My Beloved Parents

&

Honorable Teachers

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Author

Md. Masud Rana

Abstract

Harvesting is one of the key labour intensive works in rice cultivation. Production cost of rice becomes high due to labor shortage and high wage rate during harvesting time. Different types of combine harvesters have been used for harvesting rice in Bangladesh for several years. Thus, this study was carried out to compare field performance during harvesting time field efficiency (E_f), effective field capacity (EFC), fuel consumption (FC), harvesting loss (H) and harvesting cost among a large combine harvester (LCH), medium combine harvester (MCH) and manual harvesting of rice under similar field conditions. The field performances of these rice harvesting methods were measured during boro rice harvesting season of 2019. The EFC for LCH, MCH and manual in harvest operation were found to be 0.617 ha/hr, 0.376 ha/hr and 0.0042 ha/hr, respectively. The field efficiency for LCH, MCH and manual in harvest operation were found to be 80.04%, 86.79% and 72.92%, respectively in terms of time and operation. For the fuel consumption, LCH consumed more fuel (34.40 L/ha) as compared to MCH (33.80 L/ha). The harvesting losses for LCH and MCH were 3.49% and 3.06%, respectively. The loss in manual harvesting was reported to be 7-20%. The results showed that manual rice harvesting cost was 15000 Tk/ha, on the other hand, harvesting cost using large combine harvester and medium combine harvester were found 6713 Tk/ha and 5626Tk/ha, respectively. In the socio-economic and land condition of Bangladeshi farmers, rice harvesting operations can be done by using medium combine harvester.

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BADC	Bangladesh Agricultural Development Corporation
BBS	Bangladesh bureau of statistics
DAE	Department of Agriculture Extension
E_f	Field efficiency
EFC	Effective field capacity
FC	Fuel consumption
FMI	Field machine index
HYV	High Yield Variety
LCH	Large combine harvester
MCH	Medium combine harvester
TFC	Theoretical field capacity
WB	World Bank

Chapter-I

INTRODUCTION

Agriculture is the key of the development of modern civilization where by farming of domesticated species created food supplies which nurtured the development of the civilization. As like many other developing countries in the world, Bangladesh is also dependent on the agriculture. The performance of this sector has significant impact on major macro-economic objectives like employment generation, alleviation of poverty, human resource development and food security. It is the largest employment sector in Bangladesh which employs 40.15% (BBS, 2018) of the total labor force and contributes 14.10% of the country's GDP (Bangladesh Economic review, FY-2018). Agriculture accounted for 90% of the reduction in poverty between 2005-2010 in the whole world (WB, 2016).

Total population of Bangladesh is estimated to be 163.05 million (BBS, 2019).The population of Bangladesh is still growing and is expected to reach 200 million by 2050 (UN World Population Prospects, 2012). In the present situation, due to the rapid growth of population the cultivatable land resources are decreasing day by day. Hasan *et al*. (2013) distinguished the land resource of the country into two categories, i.e. agriculture lands and non-agriculture lands. A declining trend was observed for the total agricultural lands of the country. A total of 561,380ha agricultural lands were decreased during 1976-2000 and this figure was increased to 565,370ha during 2000-2010. Yearly average loss of agriculture lands were 23,391ha and 56,537ha during 1976-2000 and 2000-2010, respectively. This indicates that agriculture lands were transforming to other activities in higher rates between the years of 2000 and 2010. Annual loss from crop agriculture was found to be 68,700ha. According to FAO (2014) annual agricultural land loss (decrease) was about 0.49%.

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. Rice (Oryza sativa L.) is the main staple crop of Bangladesh accounting for 80% of total cropped area and 95% of cereals production. Bangladesh is the 4th largest rice producing country in the world due to the use of high yielding varieties (HYV) and modern rice production technology instead of local variety and traditional production technology. Bangladesh was producing about 34.86 million tons of rice to feed the growing population (Kabir *et al.,* 2015). Rice production of Bangladesh needs to be increased to feed the growing population of the country with a limited land resource. The production of rice is increased to 38.2 million tons in the fiscal year 2018-19, according to production report and Boro estimation. Therefore, it is necessary to increase productivity of limited land, cropping intensity and grow high yielding variety (HYV) of crops improving cropping pattern with cost effective technology by agricultural mechanization.

Bangladesh has achieved tremendous growth in rice production due to increased cropping intensity 192%; higher adoptions of HYV rice in dry (99%) and wet (90%) seasons (Nasim et. al., 2018). Now farmers are growing hybrid varieties.

Over the past two decades mechanization in agriculture has been accelerated. Main constraint of the mechanization process was the shortage of power but with the country's development the situation has overcome. In 1960 the farm power available for unit ha was only 0.24 kW, gradually increased to 0.32 kW in 1984 but in 2007 this amount has increased to 1.17kW/ha (Roy & Singh, 2008). According to Gurung *et al*. (2017) the used farm power per hectare of cultivable land was only 1.578 kw/ha, which was quite inadequate to sustain farming operation profitably. Recently in 2019-20 power is seemed to use about >3.0 kw/ha.

Present government has realized the shortage of farm machinery and inspires farmers to the mechanization process by subsidizing 25-60% of the farm machinery price which boosts the process of mechanization (Wohab, 2016).

In paddy cultivation, transplanting, harvesting and threshing are the three major labour intensive operations. Harvesting and threshing are the most important operations in the entire range of field operations, which are laborious involving human drudgery and requires about 150-200 man-hrs/ha for harvesting of paddy alone (Salassi and Deliberto, 2010; Veerangouda *et al.,* 2010).

Traditionally, paddy is harvested by manual labour using sickles. Furthermore, changing of the lifestyle of rural people, farm labours migrate from rural area to urban area. As a result, availability of labors is decreasing day by day at peak time. Without mechanization, there is no way to meet this deficiency of farm labours. Due to the non-availability of labours, crop harvesting is often delayed which exposes the crop to fancy of nature. Timely harvesting is utmost important, as delayed harvesting leads to a considerable loss of grain and straw owing to over maturity resulting in loss of grains by shattering and also hampers the seed bed preparation and sowing operations for the next crop. The paucity of labour force is forcing the farmers to go for crops, which are more remunerative and less labour intensive, thus affecting the paddy production (Veerangouda *et al.* 2010).

Due to increase of cropping intensity and production of different crops, the demand of agricultural labour has increased significantly. The labour scarcity is very high during the harvesting period of wheat and boro rice (Ahmmed, 2014). On the other hand, many agricultural labours have been migrating to other off-farm activities like garments and other industries, transportation, small business, road and building construction, etc. Due to delay harvesting, a large quantity of grain is lost each year in the country. Bala *et al.* (2010) reported that post-harvest losses of rice at farm level were 9.49%, 10.51% and 10.59% for aman, boro and aus season, respectively.

To reduce the harvesting loss and cost, timely harvesting of paddy and wheat is very important. A well designed, combine harvester can play an important role in harvesting of paddy and wheat in time, efficiently with less cost. There are different types of combine harvesters introduced by different traders and DAE (Department of Agriculture Extension). Farmers are very often used them along with manual method of harvesting.

The quality of these machines sometimes is questionable in terms of durability. It is therefore not surprising that even for farms that are fortunate to have access to the combines; they are abandoned after only a short time of use due to frequent breakdowns coupled with lack of after sales services. As rice production in our country is largely small-scale, it is inappropriate to procure a larger combine harvester for a relatively smaller area of cultivated rice. In these conditions, introducing mini combine harvesters would be an effective solution to reduce production cost and enhance labour productivity.

Typically, rice harvesting service providers use a large combine harvester to harvest rice in Bangladesh. However, the use of a large and heavy combine harvester in a rice field could damage the soil and break the hardpan. Recently, several rice harvesting service providers have initiated the use of a medium combine harvester which is smaller and lighter than the large combine harvester. However, there are some studies conducted to compare the performance of these combine harvesters in Bangladesh. Bawatharani *et al.* (2015) claimed that the performance of any combine harvester varied with respect to the field and the machine operational conditions. Thus, several investigations with different types of rice varieties at various field conditions were needed to study the performance of different types of combine harvesters to optimize the operational factors (Chegini, 2013; Hossain *et al.*, 2015).

Boro is the dry-season irrigated rice planted from December to early February and harvested between April and May according to Shelly *et al.* (2016). Biswas (2017) repeated that Seedling raising activities are started at onset of winter (Nov- Dec). About 30-40 day seedling are transplanted in Dec-Jan. Fifty five percent of the country's total annual rice output was in boro season.

Harvesting starts soon after the crop ripens to prevent rot or damage from weather or insects. Rice ripens in different times of the year, depending on variety, so that harvesting of one may begin while the other is yet to reach maturity. High yielding boro was harvested during May-June according to Banglapedia national encyclopedia of Bangladesh (2015).

The average paddy equivalent cost for the five major operations (tillage, transplanting, weeding, harvesting and threshing) was ranged between 37-47% of total paddy production cost. The mechanized transplanting and harvesting may reduce rice production cost largely as well as would resolve the labour scarcity problems according to Islam and Kabir (2017). Therefore, transplanter and harvester have the great prospect of widespread adoption for rice cultivation.

However, to ensure that the appropriate modifications can be made on these imported rice harvesters to suit local conditions and meet farmer acceptability, it is important to evaluate the performance of these machines under local field conditions. This approach would also offer farmers first-hand experience and help address their doubts on the extent of grain quality and losses associated with these machines to better inform future decisions on adoption of the technology.

This study was undertaken to evaluate the technical and economic performance of combine harvesters available in farmer's fields and to find out the suitability of the machines in the socio-economic conditions of the farmers of Bangladesh.

Objectives:

The main purpose of this study was to compare the field performances among large combine harvester, medium combine harvester and manual method for rice harvesting under similar field condition in Dinajpur district. The specific objectives were:

1. To study the performance of two combine harvesters in respect of field capacity, field efficiency, fuel consumption and grain losses.
2. To determine operating costs of the combine harvesters and manual harvesting method.
3. To compare the harvesting costs of combine harvesters with manual method of rice harvesting.
4. To suggest recommendation for suitable harvesting method.

Chapter-II
LITERATURE REVIEW

Many research works had been guided by many researchers to investigate the field performance of large and medium combine harvester and identify different kinds of harvesting losses during operation and recommend which is more preferable in terms of cost and performance. Review on the available literatures related to the present study has been presented below.

Wagiman *et al.* (2018) stated that a mini combine harvester has been introduced into harvesting industry to be a low-cost alternative for a large combine harvester. Thus, the study was carried out to compare the field efficiency (FE), effective field capacity (EFC), fuel consumption (FC), and field machine index (FMI) between a mini combine harvester (MCH-75 kw) and large combine harvester (LCH-100 kw) under similar field conditions. The field performances of the combine harvesters were measured during harvest operation in two consecutive seasons. The EFC for both MCH and LCH in harvest operation were found to be 0.91 and 1.30 ha/hr, respectively. In terms of the FE, MCH had 0.78% higher efficiency than LCH. For the FMI, LCH and MCH had 0.86 and 0.87, respectively. For the FC, LCH consumed more fuel (14.51 L/ha) as compared to MCH (14.25 L/ha). T-test statistical analysis showed that there was no significant difference between LCH and MCH for FE, EFC, FMI and FC. The results suggested that MCH was more efficient and economical in conducting the harvesting operation in a rice field.

Hossain *et al.* (2015) evaluated the technical and economic performance of combine harvester available in farmer's field and farmer's perception regarding the use of combine. Labour scarcity, harvesting loss, timely harvesting and harvesting cost were crucial in rice and wheat harvesting in Bangladesh. Field tests of two new (CLASS and Daedong) and two refresh (Kukje and Anower) combine harvesters were conducted for harvesting rice and wheat in the farmer's field of Jessore, Pabna, Dinajpur and Thakurgaon districts during 2011-12. Primary data were collected from 30 adopter and 30 non-adopter farmers from each district of Bogra, Rangpur, Dinajpur and Thakurgaon through direct quizzing during 2012-13. Information was also collected from different combine harvester traders available in Bangladesh.

Average time, cost and grain saving by combine harvester over manual methods were 97.50, 35.00 and 2.75%, respectively. Benefit cost ratio of CLASS, Daedong, Kukje and Anower combine harvesters were found to be 2.68, 2.11, 2.29 and 2.70, respectively. The payback periods of refresh combine harvesters were lower than the new combine harvester. There were some mechanical problems observed in refresh combine harvesters during field operations. New harvester was observed almost trouble free and popular to the famers. Scarcity of spare parts and mechanic service were the main problems for repair and maintenance of the combine harvesters in farm level. They suggested that, considering the technical performance of combine harvester and demand of the farmers, new combine harvester might be introduced in commercial basis in Bangladesh.

Veerangouda *et al.* (2010) showed that the effective field capacities with tractor operated combine harvester were different due to different forward speeds of machine. The highest effective field capacity of 0.81 ha/h was observed for a machine forward speed of 3.00 km/h. The average values of field efficiency for paddy with tractor mounted combine harvester were found to be varying from 67.02 to 76.83 percent. The harvesting losses were in the range of 2.88 to 3.60 per cent for paddy harvesting. The cost of operation was lesser for tractor operated combine harvester as compared to manual method by 57.65 to 65.55 %.

Praweenwongwuthi *et al.* (2009) reported the production of the best quality Hom Mali rice in Tung Kula Ronghai (TKR) area of Northeastern Thailand was accounted for one-third of the 9.2 million ton of rice exported in 2007. Due to a growing labor shortage in those years, adoption of combine harvesters became widespread in the TKR. The objectives of the research were to study the impacts of adoption of combine harvesters on the Hom Mali rice agro ecosystem in the TKR and describe the coping strategies farmers employ to cope with those impacts, in order to better understand the socio-economic impacts of combine harvesters in the TKR. It was found that socio-economic impacts on rice farmers due to the use of combine harvesters included an increase of 30.3 % in net benefits compared to manual harvesting, and 28 % of migrant labour could continue working in the city.

Keerti and Raghuveer (2018) explained that mechanical harvesting done by combiner harvester, which introduced in the early 1990s. Mechanical harvesting could reduce labour cost and save time to a greater extent. Combined harvester cost about Rs 800 per acre within one and half hour but manual harvesting requires minimum of 7-9 man days to harvest one acre and costs about Rs 2022 – 2600 per acre. The average fuel consumption of the combine harvester was 15 liters per acre. This indicated that combiner was an efficient, economical and less labour and time consuming machine.

Hassena *et al.* (2000) described the wheat harvesting and threshing technologies in Arsi Region, southeastern Ethiopia, and assesses their profitability compared to that of alternative wheat harvesting technologies. Data were collected from a random sample of 160 farmers from two purposively selected districts, Asasa and Etheya, where harvesting and threshing operations were becoming increasingly mechanized. Log it analysis showed that proximity to a hiring station, topography (accessibility), education level, and wheat area significantly affected farmer's decisions to adopt combine harvesting. Promoting the use of combine harvesters would widen yield and income gaps between farmers living in accessible and inaccessible areas, which had negative implications for overall economic development. Policies needed to be directed towards the introduction of intermediate technologies for wheat threshing in less accessible areas. Educated farmers were better aware of the yield loss and consequent economic loss of using traditional harvesting and threshing methods. All farmers, particularly those without an education, needed to be informed of the benefits of combine harvesting to increase adoption and reduced yield differences between literate and illiterate farmers. The profitability analysis determined that combine harvesting reduced yield losses, costs, processing time and increased profitability. At the national level, the costs of combine harvesting were much lower than those incurred at the farmer level. Financial and economic profitability analyses indicated that combine harvesting was more profitable for the nation than manual harvesting and threshing.

Spokas *et al.* (2016) reported the experimental research of a middle-size combine harvester when used for harvest of winter wheat and spring barley in heavy harvest conditions. Based on the results obtained, it was possible to determine the effect of field conditions on the crop mass flow in combine harvester, grain losses, fuel consumption, and combine harvester field performance. It was found that grain moisture content and conditions of the crop stand had a significant effect on the work indicators of the combine harvester when compared with its technological parameters and crop mass flow.

Poungchompu *et al.* (2016) collected primary data purposively from 85 operators and randomly 729 farmers with statistical analysis. Results of the study indicated that the harvesting cost of 798.48 THB/rai for using a combine harvester in wet season was smaller than the cost of manual harvesting of 1,542.17 THB/rai. The important factors affecting the use of combine harvest were farmer's education, farm size and family size. Net return from this service business was over 250 THB/rai or over 35 % of total profit that it was economic benefit for operators. But, the operators faced high cost of fuel and of repair and maintenance cost due to unskilled operation. Thus, they suggested that the government should establish a network of harvester service operators as well as encourage more maintenance training for local operator in order to high utilization efficiency in rice combine harvester. Also, the government should support farmer to expand their farm sizes by the establishment of a group farmer to easy access the use of rice combine harvester and should give wider farmer awareness education for higher adoption of combine harvester use.

Tahir *et al.* (2003) conducted experiment using combine harvester (Class Denominator) by determining harvesting losses, timeliness of harvesting, field capacity, fuel consumption, noise and dust pollution, frequency of repair/maintenance and operating cost of the machine. The results indicated that combine had an average harvesting loss of about 1.25% of wheat yield. Grain breakage losses (5.7%) were bit higher. The machine was able to harvest 2.5 to 3.0 acres in an hour. The fuel consumption of the combine was found to be 15 L of diesel per acre. As the machine was not equipped with a proper cab, dust and noise pollution posed threat to the operator's health. The machine needed only two to three persons for its operation and costs about Rs 860/acre to the user. The combine was an efficient, economical, labor and time saving machine but its initial cost was quite high. To promote this high cost technology, it was suggested that the District Governments of present set up should make arrangements at Tehsil Council level to provide combine to the farmers on rental basis.

Suleiman and Dangora (2017) evaluated the performance of Deutz-Fahr (M1202) combine harvester on rice crop in Agricultural Engineering Department research and demonstration field, Bayero University, Kano. The experiment was run in a completely randomized block design based on three independent variables which included: forward speed of the machine, 3 levels each of moisture content of the crop and clearance. Field experiments were conducted at 1.70 km/hr constant speed. The results showed that theoretical field capacity, effective field capacity, field efficiency and mean fuel consumption were 0.77ha/hr, 0.68 ha/hr, 88 % and 45 L/ha respectively.

Afify *et al.* (2000) mentioned four harvesting systems (manual + thresher, tractor mounted mower + thresher, Deutzfahr combine, and Yanmar combine) with three planting methods (manual transplanting, drilling, and mechanical transplanting) tested to select the proper system of rice harvesting which suits the planting method. They found that the least costs of planting, harvesting, and percentage of losses were 104.21LE/fed., 84 LE/fed. and 2.18% respectively obtained by using of drilling system and harvesting by DeutzFahr combine.

Alam *et al.* (2017) conducted a study determining the cost of use of harvesting machine in Doyalsara, Bogra and Mymensingh region. Data were collected for rice in the Aman and Boro season of 2015 to determine the cost of harvesting by combine harvester and reaping and threshing by reaper and thresher. It was found for combine harvester operational cost and for carrying rice bag and straw to the plot side Tk.10, 447/ha. On the other hand, for reaper and thresher, the reaping, binding, carrying the rice to the plot side, threshing and cleaning required Tk.6,940/ha. The percentage of cost of combine harvester in relation to reaper and thresher for the same work was higher by 50.53%. In the socio-economic condition of Bangladeshi farmers, harvesting and threshing operations were done by using self-propelled reaper and close drum thresher was found cost effective and reasonable.

Culpin (1986) Smith and Wilkes(1976) the sources of total grain losses on the combine harvester to be pre-harvest losses, shattering loses, threshing losses, straw walker losses and shoe losses. To reduce grain losses, the operator must know the source of losses and how to measure losses. If the grain losses were not acceptable, the operator must reduce them by adjusting the components, which caused the costly losses. The losses from improperly adjusted combines could be quite significant. It was reported that in 1985, wheat farmers in Oklahoma lost $37 million in grain due to combine cleaner losses, a large portion of which could have been prevented by proper adjustments. Researchers at Oklahoma State visited various combine operations in the field and checked the grain losses from different machines (Downs *et al.,* 1985). They found that the average for machine related losses was 5% of total yield. Most experts agreed that correctly adjusted and operated loss should be between 1 and 3% of the total yield (FMO, 1987).

Moghaddam (2007) reported that the average of combine losses was about 4-5% in advanced countries, unfortunately in Iran. It was about 20% and higher. The loss of combine harvester was divided to natural loss (preharvest loss), platform cutting loss (head loss), threshing loss, cleaning loss and the loss of body (Hunt, 2001). In order to reduce loss, it was necessary that product process such as cutting, conveying, threshing, separating and, etc. should be optimized. One way to optimize these processes was the breakdown of processes and division of these to smaller elements. Threshing of grain was a most important process which had more effect on combine performance. An ideal threshing unit was one that produced a perfect thresh of a maximum throughput, with optimum grain separation, while it preserved crop quality, minimized grain loss and fragmentation and separation (Miu, 1999).

El-Khateeb (2005) tested multi-purpose combine harvester (Yanmar model CA-760) for harvest rice crop, and found that the maximum value of actual field capacity was 2.90 fed/h at forward speed of 3.0 km/h and grain moisture content of 18 %. Also, he found that the highest value of fuel consumption rate was 7.20 L/fed at forward speed of 1.5 km/h and grain moisture content of 25%. He recommended that grain moisture content of 22.0 %, forward speed of 1.5 km/h, cylinder speed of 24.0 m/s were the optimum operating conditions for mechanical harvesting rice crop. Also, using combine harvester was the most efficient and economic system (89.70 L.E/fed) compared to manual harvesting and gathering followed by threshing and winnowing (181.60 L.E/fed).

Ghonimy and Rostom (2002) developed an overall criterion for evaluating four types of head feeding combines (YANMAR CA-32, YANMAR CA-385EG, KUBOTA R1-40 and KUBOTA PRO-48). It depended upon the relative weight for each technical and economical evaluation criterion. This overall criterion was suitable for mechanization services suppliers by using (operating hour costs) as economical evaluation parameter and suitable for the farmers (mechanization services users) by using (renting costs) as economical evaluation parameter. The combines' arrangement according to the final overall criterion for the farmers (mechanization services users) was PRO-48, CA-385EG, R1-40, and CA-32. El-Sahrigi and Khan (1990) reported that reapers had been used for harvesting wheat and rice, however, the output of the reaper was low and considerable labor was still required for collection, threshing, and bagging seeds.

Omran (2007) carried out a study at the field of Rice in the Mechanization Center, Meet El-Deeba, Kafer El-Sheikh Governorate during harvesting season of 2007. Five of the most widely wheat harvesting systems were studied on the widely common wheat cultivar (Sakha93): multi-purpose combine harvester, through in combine harvester, hold in combine harvester, Reaper + thresher and double knives mounted mower + thresher to recommend the appropriate system for harvesting wheat crop. The systems were evaluated according to the technical parameters: actual performance rate, field efficiency; cutting efficiency, cleaning efficiency; percentage of the total losses and consumed energy, according to (RNAM, 1995) and according to the financial criteria. Overall cost criterion was used to evaluate the tested wheat harvesting systems. The results showed that the combine harvester realized the highest actual performance rate (3.06 fed./hr) at all the tested forward and threshing speeds compared with the other studied systems. The highest field efficiency (94.3%) was obtained from the Reaper + thresher and double knives mounted mower + thresher systems. The highest cutting efficiency (94.3%) was conducted by hold in combine harvester. The highest cleaning efficiency (98.7%) resulted from Reaper + thresher and double knives mounted mower + thresher systems at threshing drum speed 35.34 m/s. The lowest percentage of total grain losses averaged (2.27%) resulted from the hold in combine harvester system. The lowest consumed energy per fed. and per ton was achieved by multipurpose combine harvester. The lowest significant total cost (85.72 LE/hr) resulted from Reaper + thresher system. The overall cost criterion (LE/fed.) was observed from harvesting systems; it included actual performance rates, consumed energy, cost of total losses grain, and total costs. The lowest value was considered the most appropriate from operation of multi-purpose combine harvester.

Sanaraweera (2012) showed that in Sri Lanka, Based on the farmers' view, 73.33 per cent of the farmers stated that cost of production can be minimized due to combine harvesters. The average production cost per acre, in case of machinery harvesting was Rs 6500 and that for manual harvesting was about Rs 10,500. Rest of the farmers said that there weren't significant difference between manual harvesting and mechanical harvesting. Production cost of two farm groups (Using harvesters and not using harvesters) were considered.

Chiansuwan *et al.* (2002) showed that the off-season rice harvesting losses up to 85% losses were mainly caused during the screening and cleaning process, whereas very small losses occurred during harvesting and threshing process.

Hassan and Larson (1978) reported the combine capacitive performance data gathered in time studies of sorghum harvesting. They recorded the activities using time study board and stop watches on harvesting, turning, emptying tank, travel to and from trailer, cleaning, minor maintenance and adjustment of machine and operator personal time. These data were used to compute effective field capacities and field efficiencies. The time studies revealed average effective field capacity and field efficiency to be 1.42 ha /h and 72%, respectively. The average forward speed and machine width were 4.04 km /h and 5.69 m, respectively.

Fouad *et al.* (1990) studied the performance of a self-propelled German harvester on rice harvesting in Egypt. The specifications of rice harvesting Deutz-Fahr (M 980) combine harvester with 54 kW diesel engines were 3 m of cutting width, 1030 mm wide and 560 mm diameter of peg type drum and operated at 800 rpm. Drum-concave clearance was adjusted to15 mm in front and 7 mm in rear according to the instructions. They found the grain loss was178-380 kg/ha for Ryhe variety rice where grain losses increased with the increased forward speed (0.8-2.9 km /h). The field efficiency was increased from 54 to 82% with a reduced forward speed from 2.9 to 0.8 km /h where time losses were counted for turning, grain unloading and removal of straw clogging for the same variety of rice in the field soil moisture content of 30-32.7% during the harvesting.

Prakash *et al.* (2009) carried out field evaluation trials of a tractor operated combine harvester for harvesting of paddy crop as per RNAM and BIS test codes in farmers' fields. The studies were also conducted for comparing the cost of operation and saving in the cost over manual harvesting. The width of the cutter bar was 3.5 m and the average value of effective field capacity of the machine was found to be from 0.64 to 0.81 ha /h with field efficiency of 67.02 to 76.83 percent.

Kamaruzaman *et al.* (2001) investigated the performance and grain losses of a New Holland (Clayson 1545) European self-propelled conventional all-crop combine harvester. They used it in a commercial farm where MR211 rice variety was being cultivated. The average width of the cutter bar was 3.92 m and the average field capacity of the machine was 1.05 ha /h with an average field efficiency of 72%.

Kalsirisilp and Singh (2001) modified a Thai-made 108 kW rice combine harvester by replacing the cutter bar system with a stripper header. The power requirement of the modified machine was measured at no load and during field operation. The stripper header system consisted of a 3 m wide stripping rotor, a metal hood and an adjustable nose. The outer diameter of the stripping rotor was 450 mm. The stripping rotor consisted of eight rubber blades fixed on an octagonal drum with each blade having 71 teeth. The work rate and harvesting losses were measured to examine the field performance of the modified machine. Results obtained from the test showed that the power requirement for the whole machine during field operation at 1600 min-1 was 58 kW. The threshing, traction and strip per header units consumed 11.4, 22.8 and 16.9 kW, respectively and the power transmission loss was 6.9kW. For standing crop, the average field capacity of the machine was 0.66 ha /h with a corresponding field efficiency of 74%. In a lodged crop condition, the average field capacity was found to be 0.3 ha /h with a corresponding field efficiency of 72%. The total grain loss of the machine was 4% of grain yield in the standing crop condition and 5.6% in the lodged crop condition. No major mechanical or operational problems were observed during field operations.

Smith and Wilkes (1976) mentioned that the rate of work of a combine depended on the size, rate of travel and yield of grain. The capacity of a small grain and soybean combine of 4.2 m cutter bar was 15-20 ha day-1. For the soft soil, it reduced to 10 ha day-1 (or 1.2 ha /h) for the same combine where per day working hours was 8 h.

Amponsah *et al.* (2017) showed that the combine worked satisfactorily on less dense rice fields with minimal weeds at grain moisture contents between 19.1% and 20.1% wb. on soils with moisture content from 23% to 33% db. while causing no significant changed to soil physical properties. With harvesting speed ranging from 0.8 to 4.5 km/h, the harvester had a field capacity of 0.10 to 0.39 ha/h and consumed fuel of up to 11 L/ha while having track slip of 6% to 9%. Harvesting using 2- and 1-L gear offered the best efficiency for IR841 and Nerica L20 rice varieties, respectively. As harvesting speed increased, harvesting efficiency decreased and crop throughput increased irrespective of rice variety. The combine produced low mechanical grain damage with total grain loss ranging from 1.43% to 4.43% and 1.85% to 5.6% for the IR841 and Nerica L20 rice varieties, respectively. At an investment cost of US$5000 and hiring at US$10 per h, owning the mini combine harvester became profitable after 342 h of machine use; equivalent to approximately 133 ha of paddy field harvested at a harvesting capacity of 0.39 ha/h. Further testing of the combine under a wide range of crop and soil conditions across different agro-ecological zones and economic comparison with manual harvesting was recommended. This would offer smallholder farmers diverse options of rice harvesting mechanization to facilitate future adoption of improved technologies.

Ali *et al.* (2018) ensured the agricultural mechanization, especially in rice harvesting system to increase production and cropping intensity. The main objective of the study was to identify the present rice harvesting practices in southern delta of Bangladesh and was also to assess the manual and mechanical harvesting systems of rice with impact on socio-economic status of Bangladesh by reducing labor cost, infield harvesting losses and harvesting time. Several experiments were conducted to compare between mechanical and manual harvesting systems. Mechanical harvesting of Aman-2016 rice and Boro-2017 rice was conducted using reaper and a mini-combine harvester at Dumuria and Wazirpur Upazilas of Khulna and Barisal districts, respectively of Bangladesh. Manual harvesting of rice was also conducted at the same locations. The results showed that manual rice harvesting cost was 24400 BDT/ha, and on the other hand, harvesting cost using mini-combine harvester and reaper were found 10123 BDT/ha and 13152 BDT/ha, respectively. Harvesting loss of rice could be reduced to 5.12% and 2.14% using mini-combine and reaper, respectively in comparison to manual harvesting system. Farmers could invest the financial benefit of mechanical harvesting system to other agricultural sectors like poultry, fishery, fruit and vegetable production. As a result, total agricultural production might be increased and helped to contribute significantly to the development of socio-economic status of rural community of the Bangladesh.

Pawar *et al.* (2008) conducted experiment on combine harvester at MPKS Rahuri in wheat crop. They observed that total field loss of combiner harvester (4.20 %) was less than the combination of reaper with thresher (10.57 %).

Chapter-III

MATERIALS & METHODS

3.1 Study area

The experiment was conducted in research farm of Bangladesh Agricultural Development Corporation (BADC) Nashipur, Dinajpur in 2019.This research was conducted at three different rice fields (Field A, Field B and field C), located at Kaushalpur B-block, Nashipur, Dinajpur. Thirty days old seedling of BRRI dhan29 was transplanted during 26-27 January, 2019 by mechanical rice transplanter. The seedlings were collected from seed bed in BADC farm. Around 120 days the rice was ready for harvesting. Here harvesting of the rice was done on 29 May 2019.

A B C

Fig-3.1: Study sites (Kaushalpur B-block, Nashipur, Dinajpur). A for large combine harvester, B is for medium combine harvester and C is for manual harvesting.

For harvesting field A and field B was divided into three areas namely area 1,area 2 and area 3.Field A was allocated for a large combine harvester (LCH),Field B for a medium combine harvester (LCH) and other field C for manual harvesting (shown in Fig-3.1). After identifying the location of the site, the experiments were conducted during boro rice harvesting season.

The sizes of the plot area are given bellow in Figure-3.2, Figure-3.3 and Figure-3.4, respectively.

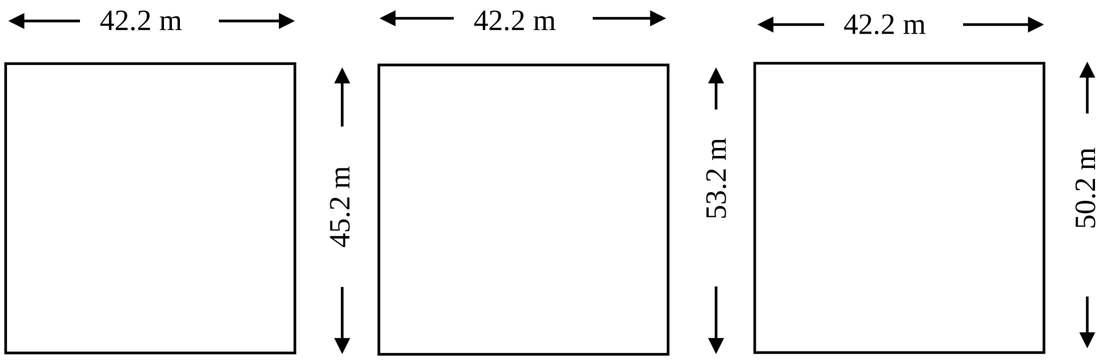

Fig-3.2: Harvested area size by large combine harvester in field A.

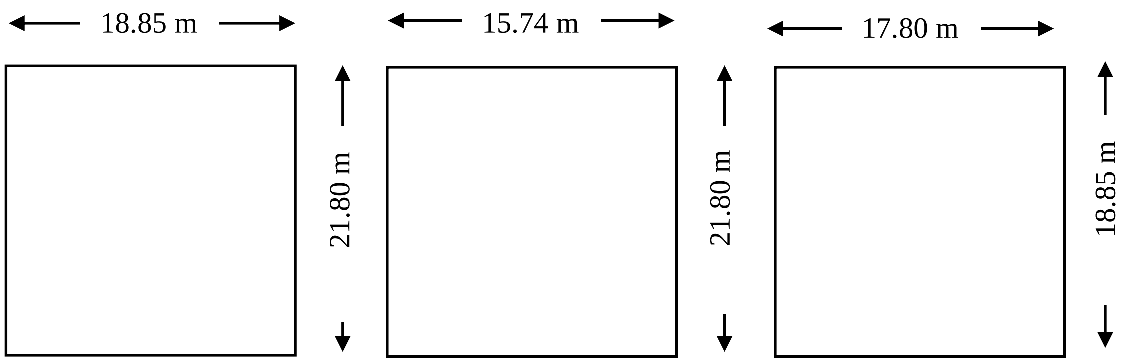

Fig-3.3: Harvested area size by medium combine harvester in field B.

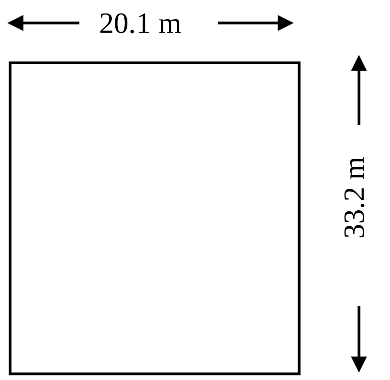

Fig-3.4: Harvested area size by manual harvesting in field C.

3.2 Combine harvester

Functional components of combine harvester have the five major operations during the harvesting. These may be classified as (1) cutting the crop and feeding to the threshing cylinder (2) threshing the grain from ear head (3) separating the grain from the straw (4) cleaning the grain and (5) handling the grain after threshing according to Veerangouda *et al*, (2010). These operations are performed automatically as the material is moved through different systems of combine harvester.

Fig-3.5: Medium combine harvester (MCH)

Fig-3.6: Large combine harvester (LCH)

There were two types of combine harvesters used in this study namely LCH and MCH. One model of combine harvester were chosen for the Medium Combine harvester (MCH) namely WORLD DR 150-A (Figure-3.5) and one for the Large Combine Harvester (LCH), it was represented by CLAAS (Figure-3.6). The selections of these two different models were made since these models were predominantly used by authority of BADC in the site.

The specifications of the combined harvesters are given in the Table-3.1.

Table 3.1 Specification of the combine harvesters

Specification	Type of Combine Harvester	
	LCH	MCH
Brand name	Class	World
Model	CROP TIGER 30	DR150A
Made in	India	China
Wheel type	Wheel	Crawler
Grain delivery system	1000 kg storage tank delivered with mower	600 kg storage tank delivered with mower
Feed type	Reel push	Head feed
Maximum engine power, hp	60 hp	48 hp
Implement width, m	2.477	1.283
Total body mass, kg	4270	2600
Fuel tank capacity, L	100	75
Engine rotation speed, rpm	2800	2700
Price, Tk.	4000000	1800000
Life time, years	10	10

3.3 Methods

3.3.1 Speed of travel (forward speed)

Speed of travel may be defined as the speed through which harvester cutting the crop in the field during harvesting. For measuring forward speed of the combine harvester while harvesting the crop, the distance traveled by the combine harvester in few times were measured by measuring tape and the stopwatch. The speed of travel was recorded in terms of km/h. For medium combine harvester average forward speed was 3.375 km/hr, and for large combine harvester average forward speed was 3.1112 km/hr, respectively.

Fig-3.7: Distance and width measurement

3.3.2 Cutting width

Cutting width may be defined as the width at which harvesters cut the crop land in one ups or downs. Two types of cutting width were found. They were rated cutting width and actual cutting width. For rated cutting width we measure the width of cutting equipment before harvesting was started and for measuring actual cutting width at which harvester cutting the crop in the field. Three cutting widths were taken for both combine harvesters during the performance time by measuring tape. For medium combine harvester average cutting width was 1.283 m and for large combine harvester average cutting width was 2.477 m, respectively.

3.3.3 Time losses and effective operating time

According to Kepner *et al.* (1982) time losses while harvesting crop was the time for adjustments, turning at the row end, cleaning machine, idle travel, fueling etc. The start and finish time of harvesting in each plot was also recorded. Different time losses were recorded by stopwatch.

3.3.4 Theoretical field capacity

It is the rate of field coverage of an implement that would be obtained if the machine were performing its function 100% of the time at the rated forward speed and always covered 100% of its width. According to Kepner *et al.* (1982) the theoretical field capacity was calculated by the following equation:

$$TFC=\frac{SW}{10} \qquad (1)$$

Where,

TFC= theoretical field capacity in ha/h

S= forward speed in km/h

W=actual width of the implement in m

3.3.5 Effective field capacity

Effective field capacity is the actual rate of performance of land or crop processing in a given time, based on total field time. In other words effective field capacity of a machine is a function of the rated width of the machine, the percentage of rated width actually utilized the speed of travel and the amount of field time lost during the operation. In order to determine effective field capacity the rated width of implement (cutting width), Speed of travel and field efficiency were measured. The effective field capacity was calculated by the following equation:

$$EFC=\frac{SW}{10}\times\frac{E_f}{100} \qquad (2)$$

Where,

EFC = effective field capacity in ha/h

S= forward speed in km/h

W= effective width of the implement in m

E_f= field efficiency(%)

Again, effective field capacity can be defined as actual area covered in certain time. The equation was given below:

$$EFC=\frac{A}{t} \quad (3)$$

Where,

A= Area

t= time

3.3.6 Field efficiency

Field efficiency can be defined as the ratio of effective field capacity to theoretical field capacity, expressed as percent. Field efficiency can be determined by the flowing equation:

$$E_f = \frac{EFC}{TFC} \times 100 \quad (4)$$

Where,

E_f= field efficiency in %

EFC= effective field capacity, ha/hr

TFC= theoretical field capacity, ha/hr.

3.3.7 Determination of fuel consumption

The fuel tank of the combine harvesters were fully filled before harvesting operation. The amount of fuel consumption of the combine harvesters were determined by measuring the difference of the fuel inside the fuel tank before and after the operation.

3.3.8 Harvesting losses

In order to estimate harvesting losses by combine harvester, the losses that occurred most during performance were shatter loss (g1), cutter bar loss (g2), and threshing loss (g3). Shatter loss is the grain that falls on the ground as the grain head is shattered due to the impact by the reel. Cutter bar losses are grain head that are cut by cutter bar but fall in the ground.

Shatter losses Cutter bar losses Threshing losses

Fig-3.8: Different types of losses during harvesting operation.

Threshing losses are those unthreshed grain head that escape the combine at the rear, either with straw or with material from the cleaning shoe. To measure the losses during harvesting, eight plots of (1m × 1m) dimension were chosen from both experimental fields. Harvesting losses included shattering and uncut losses and threshing losses were determined by the following equation:

$$W_{gt}= W_{g1}+W_{g2}+W_{g3} \quad (5)$$

Where,

W_{gt}= total losses (g/m^2)

W_{g1}= shattering losses (g/m^2)

W_{g2}= cutter bar losses (g/m^2)

W_{g3} = threshing losses (g/m^2)

After measuring the amount of losses at different stages, the percentage of harvest losses were determined by the following equation:

$$H = \frac{W_{gt}}{Y_g} \times 100 \quad (6)$$

Where,

H= percentage of harvest losses (%)

Y_g= grain yield (g/m^2)

W_{gt} = threshing losses (g/m^2)

3.3.9 Harvesting costs

In order to compare harvesting costs in MCH and LCM, all the costs of wages in manual and the fixed and variable costs in mechanical operations were calculated. A fixed cost consist of depreciation cost, interest, shelter and taxes and is a function of purchase value, useful life and interest rate.

Depreciation was determined from straight-line method by the following equation:

$$D = \frac{P - S}{L} \qquad (7)$$

Where,

D= depreciation cost (Tk./yr)

P= purchase price (Tk.)

S= salvage value (Tk.)

L= lifetime of use (yrs)

Useful life for LCH and MCH was considered to be 10 and 10 years respectively. The machine salvage value was considered to be 10% of purchase value. Interest on investment is an actual cost in agricultural machinery and was determined from the following equation:

$$I = \frac{P + S}{2} \times i \qquad (8)$$

Where,

I= interest on investment (Tk.)

P= purchase price (Tk.)

S= salvage value (Tk.)

i= interest rate(%)

Tax, Insurance and shelter (T.I.S) cost were assumed 2% of the purchase value and the annual interest rate were assumed to be 13%. Variable costs included fuel, lubricant, repair & maintenance and operators & labour costs and were directly related to the amount of work done by the machine. Repair and maintenance cost of combined harvester was considered to be 0.025% of the purchase cost. Oil cost was 15% of the fuel cost for combine harvester (Kepner *et al.* 1982). Operator cost for LCH and MCH were considered to be 1000 and 700 Tk/day, respectively and labour cost was considered to be 500 Tk./day for all methods according to the local price.

For determining manual harvesting cost, we needed to find out how many labour is required for harvesting manually 1 hector of rice and wage of the labour. We hired 2 men for 1 day to harvest rice in the field where they cut rice with sickle and threshing rice with paddle thresher in the field.

Chapter- IV

RESULTS AND DISCUSSIONS

The data collected during the field performance of rice cultivation was analyzed to determine the forward speed (km/hr), field efficiency (%), field capacity (ha/hr), fuel consumption (litre/hr), losses during operation (percent of total yield) and also calculated harvesting cost by medium combine harvester, large combine harvester and manual method during harvesting of rice. Finally, compared the harvesting cost of medium combine harvester over large combine harvester and manual method.

4.1 Forward speed and width measurement

For measuring forward speed of the combine harvester while harvesting the crop, the distance traveled by the combine harvester in few times was measured by the stopwatch and the speed of travel was recorded in terms of km/h. Forward speed of large combine harvester was 3.375 km/hr and for medium combine harvester forward speed is 3.112 km/hr shown in the Table-4.1.

For measuring width again we took three cutting width for both combine harvester during the performance time and average cutting width of medium combine harvester was 1.283 m while for large combine harvester 2.477 m shown in the Table-4.1. Calculation of forward speed and width is shown in the appendix-I.

Table-4.1: Forward speed and cutting width measurement of LCH and MCH

Type of combine	Exp. no	Time (sec)t	Distance covered (m) d	Forward speed (km/hr)	Average Speed (km/hr)	Cutting width (m)	Average cutting width (m)
MCH	1	20	19.30	3.474	3.375	1.25	1.283
	2	17	15.74	3.33		1.29	
	3	18	16.60	3.32		1.31	
LCH	1	52	45.20	3.13	3.112	2.45	2.477
	2	62	53.20	3.089		2.50	
	3	58	50.20	3.116		2.48	

4.2 Cutting area measurement

A total area of 410.93 m^2, 343.132 m^2 and 335.53 m^2 of rice were harvested by MCH for 9 min, 8 min and 8 min respectively. Average cutting area of MCH was 2615.02 m^2 (0.2615 ha) per hour.

A total area of 1907.44 m^2, 2245.04 m^2 and 2118.44 m^2 of rice were harvested by LCH for 25.5 min, 29.5 min and 28 min respectively. Average cutting area of LCH was 4533.19 m^2 (0.4533 ha) per hour.

On the other hand, the total area of 667.32 m^2 of rice was harvested manually by two men in one day (Table-4.2).

Table-4.2: Time and area measurement of harvesting methods.

Type of combine	Name of field	No. of area	Starting time	Ending time	Total time required (min)	Time loss (sec)	Area covered (m^2)	Average area covered per hr. (m^2/hr) [ha/hr]
MCH	A	1	10:11	10:20	9.00	70	410.93	2615.02 [0.262]
		2	10:53	11:01	8.00	65	343.132	
		3	11:33	11:41	8.00	63	335.53	
LCH	B	1	12:37	01:37:30	25.50	305	1907.44	4533.19 [0.453]
		2	01:33	02:02:30	29.50	335	2245.04	
		3	02:27	02:55	28.00	353	2118.44	
Manual harvesting	C	–	–	–	*8×2×60	130×2×60	667.32	41.71 [0.0042]

*****1 man-day= 8 hrs.

4.3 Field efficiency

The averages of E_f from field performance in cultivation of rice seasons are shown in Fig-4.1. It was found that the E_f for the MCH and LCH and manual were 86.79%, 80.04% and 72.92%, respectively (details in Appendix-I). The E_f for the MCH was 6.75% higher than the LCH, indicating that the MCH was efficient in terms of time consumption in conducting harvesting operation. This finding was supported by the fact that the E_f increases as the width of the implement decrease (Hanna, 2016). In this study, the widths of the cutter bar for the MCH and LCH were about 1.283 m and 2.477 m, respectively.

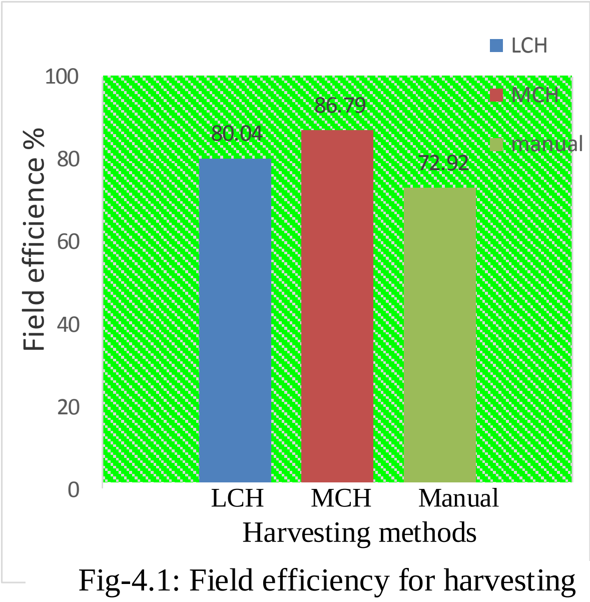

Fig-4.1: Field efficiency for harvesting operation.

4.4 Effective field capacity

The averages of EFC from field performance in cultivation of rice are shown in Fig-4.2. It shows that the EFC of the LCH and MCH was 0.617 ha/hr and 0.376 ha/hr, respectively when EFC of manual harvesting was only 0.0042 ha/hr (details in Appendix-I). This is acceptable because the MCH had a shorter cutter bar as compared to the LCH. Hossain *et al.* (2015) reported that the EFC of a combine harvester would decrease when the width of the implement decreased.

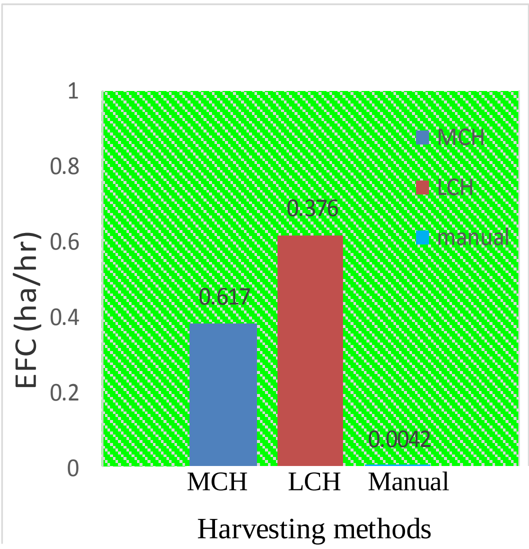

Fig-4.2: Effective Field capacity for harvesting operation

4.5 Fuel consumption

The averages of fuel consumption from field performance in cultivation of rice seasons are shown in Fig-4.3. It shows that LCH consumed 15.58 lit/hr of fuel while MCH only consumed 8.83 lit/hr of fuel (Table-4.3). This data indicated that the LCH consumed 6.75 L/hr fuel more than MCH under typical field conditions. This is true because a bigger engine will typically consume more fuel. In this study, based on Table 3.1, It is proven that the engine power of the LCH was higher than the MCH thus it consumed more fuel.

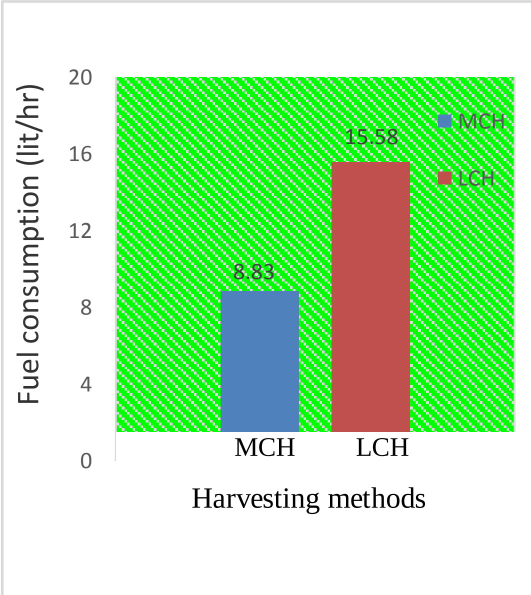

Fig-4.3: Comparison of fuel consumption for harvesting operation between MCH and LCH.

Table- 4.3: Fuel consumption of LCH and MCH

Harvester Type / Area	LCH				MCH			
	Area m^2	Quantity of Fuel (L)	Consumption rate (Lit/hr)	Fuel consumption (Lit/ha)	Area m^2	Quantity of Fuel (L)	Consumption rate (Lit/hr)	Fuel consumption (Lit/ha)
Plot 1	1907.44	6.4	15.05	33.55	410.93	1.42	9.47	34.55
Plot 2	2245.04	7.87	16.00	35.04	343.132	1.21	9.07	35.26
Plot 3	2118.44	7.33	15.70	34.60	335.53	1.06	7.95	31.59
average			15.58	34.40			8.83	33.8

4.6 Harvesting losses

The total harvesting loss refers to the summation of gathering shatter loss, threshing loss, cutter bar losses, sieve loss and rack losses. In this study shatter loss, cutter bar loss and threshing losses were measured. Sieve loss and rack loss losses were not measured (as it is negligible). The averages of harvesting losses from field performance in cultivation of rice are shown (Fig-4.4) that the harvesting losses of the LCH was 3.49% and the harvesting losses of the MCH was 3.06% (details in Appendix-I). Different type of losses in each plot of LCH and MCH is shown in the Table-4.4. Losses in manual harvesting systems can reach 7–20% depending on the season and local practices (Bautista *et al.*, 2007). Harvesting loss might vary with the operator's skill, harvesting time, soil condition and agronomic characteristics of the paddy. Kurhekar and Patil (2011), mentioned that early harvesting reduced preharvest and shattering loss in operation, on the other hand delayed harvesting caused more loss due to low moisture content.

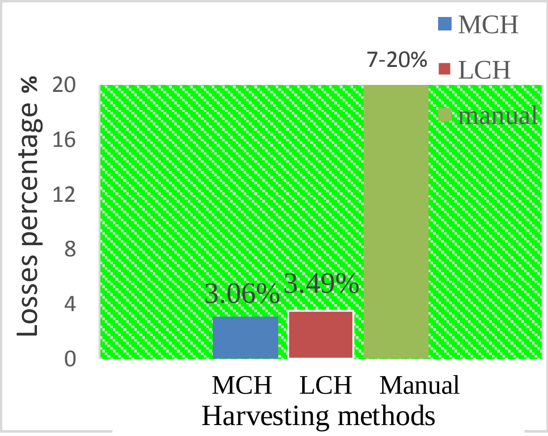

Fig-4.4: Percentage of harvesting losses during operation.

Table-4.4: Different types of loss in each plot for field A and field B in g/m^2 during harvesting operation.

Type of losses	Type of harvester	Plot 1 (g/m^2)	Plot 2 (g/m^2)	Plot 3 (g/m^2)	Plot 4 (g/m^2)	Plot 5 (g/m^2)	Plot 6 (g/m^2)	Plot 7 (g/m^2)	Plot 8 (g/m^2)	Average losses (g/m^2)	Average losses in %
Shatter losses	LCH	13.49	14.15	22.13	2.10	3.30	10.25	18.87	16.61	12.58	1.68
	MCH	10.55	13.91	4.44	5.78	3.37	15.01	10.85	9.48	9.92	1.32
Cutter bar losses	LCH	7.85	8.23	5.74	5.18	4.78	5.71	6.07	4.05	5.95	0.79
	MCH	5.71	8.51	8.20	5.39	6.26	4.12	5.77	6.45	6.30	0.84
Threshing losses	LCH	7.50	7.80	9.70	4.60	7.60	8.60	7.60	8.01	7.67	1.02
	MCH	4.32	9.77	8.55	5.34	6.50	5.86	6.22	7.69	6.78	0.90

*****From each field eight sample size plots (1 m×1 m) were selected for determining the losses.

Straw Condition:

In the large combined harvester straw was in the mass from and collected manually. In the medium combined harvester, no harm damage in the straw and straw was also collected manually.

4.7 Economic analysis

Economic performance of large combine harvesters (LCH) and medium combine harvester (MCH) in farm level is given in Table-4.5. The basic data presented in this table were collected from the combine harvester provider. Economic lives of new and refresh combine harvesters were assumed to be 10 years each, respectively. During the harvesting season, combine harvester was effectively operated for 8 hours in a day. The cost from field performance in cultivation of rice seasons are shown (Figure-4.5). It shows that cost of large combine harvester (LCH) was 6713 Tk./ha and medium combine harvester (MCH) cost was 5626 Tk./ha while cost of manual harvesting was 15000 Tk./ha (details in Appendix-II). The cost for the LCH was 1087Tk./ha higher than the MCH, indicating that the MCH more efficient in terms of economical cost analysis in conducting harvesting operation.

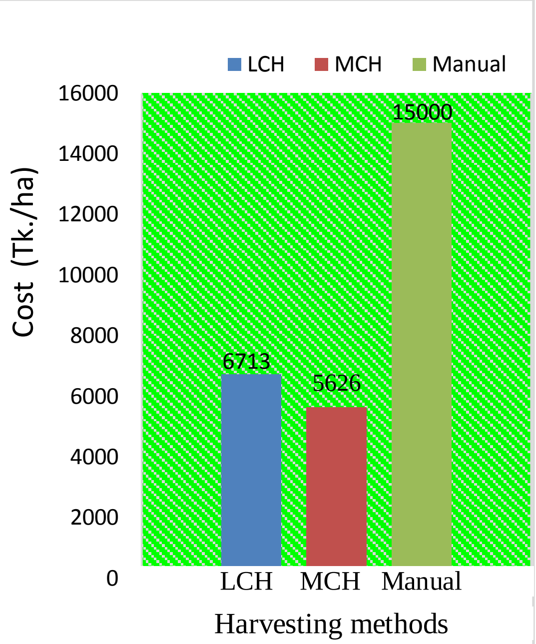

Fig-4.5: Economic performance of different harvesting operations

Table-4.5: Economic performance of different combine harvesters in farm level.

Cost items	**LCH**	MCH	Manual harvesting
	CLASS (Crop Tiger 30)	World DR150-A	30 labour per ha. Wage per labour 500 Tk./day
Fixed cost			
Price (Tk.)	4000000	1800000	
Salvage value (10% of P) (Tk./yr)	400000	180000	
Economic life (year)	10	10	
Depreciation (Tk./yr)	360000	162000	
Interest (13%) (Tk./yr)	286000	128700	
Tax, Insurance and shelter (TIS) (2% of P)	80000	36000	
Total fixed cost (Tk./yr)	726000	326700	
Fixed cost per hour (Tk./hr) (60×8 hr per year)	1512.5	680.625	
Variable cost			
Repair & maintenance cost (0.025% of P) (Tk./hr)	1000	450	
Fuel cost (Tk./hr) (70Tk./lit)	1090.6	618.1	
Oil cost (15% of fuel cost) (Tk./hr)	163.59	92.715	
Labour cost (Tk./hr)	375	275	
Total variable cost (Tk./hr)	2629.19	1435.815	
Overall cost			
Total cost (Tk./hr)	4141.59	2116.44	
Operational cost (Tk./ha)	6713	5626	15000

Chapter-V

CONCLUSION

Effective field capacities during rice harvesting for the LCM, MCH and manual harvesting were found to be 0.617 ha/hr, 0.376 ha/hr and 0.0042 ha/hr, respectively. The field efficiency of large combine harvester, medium combine harvester and manual harvesting were 85.71%, 86.87%, and 72.92% respectively. Actual field capacity and field efficiency increased with the increase of land size and operator's skill.

The averages of fuel consumption from field performance in cultivation of rice was 15.58 lit/hr for LCH and 8.83 lit/hr for MCH. This is true because a bigger engine will typically consume more fuel.

Total harvesting loss by the medium combine harvester and large combine harvester were 3.06%and 3.49% of the total yield, respectively. Due to lack of different facilities for losses calculation, here shatter loss, cutter bar loss and threshing loss was evaluated. Sieve loss and rack loss was not measured as it was very negligible.

The rice harvesting cost was 15000 Tk/ha, on the other hand, harvesting cost using large combine harvester and medium-combine harvester were found 6713 Tk/ha and 5626 Tk/ha, respectively. Harvesting cost in medium combine harvester was 9374 Tk/ha and 1087 Tk/ha less than manual harvesting system and large combine harvester, respectively. In the socio-economic and land condition of Bangladeshi farmers, rice harvesting operations can be done by using medium combine harvester (MCH) which is cost effective and reasonable.

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Appendix-1

Field performance calculation

Forward speed (F, km/hr) calculation:

We know,

Forward speed (S, km/hr)= $\frac{d}{t} \times 3.6$

Where,

S= forward speed (km/hr)

d=distance traveled (m)

t= required time (sec)

So, forward speed (km/hr) of LCH,

$$S_1 = \frac{d_1}{t_1} \times 3.6 = \frac{45.20}{52} \times 3.6 = 3.13 \text{ km/hr}$$

$$S_2 = \frac{d_2}{t_2} \times 3.6 = \frac{53.20}{62} \times 3.6 = 3.089 \text{ km/hr}$$

$$S_3 = \frac{d_3}{t_3} \times 3.6 = \frac{50.2}{58} \times 3.6 = 3.116 \text{ km/hr}$$

∴Average forward speed of LCH= 3.112 km/hr.

So, forward speed (km/hr) of MCH,

$$S_1 = \frac{d_1}{t_1} \times 3.6 = \frac{19.30}{20} \times 3.6 = 3.474 \text{ km/hr}$$

$$S_2 = \frac{d_2}{t_2} \times 3.6 = \frac{15.74}{17} \times 3.6 = 3.333 \text{ km/hr}$$

$$S_3 = \frac{d_3}{t_3} \times 3.6 = \frac{16.60}{18} \times 3.6 = 3.32 \text{ km/hr}$$

∴Average forward speed of MCH= 3.375 km/hr.

Field efficiency (E_f, %) calculation:

We know,

$$\text{Field efficiency } (E_f, \%) = \frac{\text{effective operating time}}{\text{total operating time}} \times 100$$

$$= \frac{\text{total operating time} - \text{time loss}}{\text{total operating time}} \times 100$$

Where,

E_f= Field efficiency (E_f, %).

So, Field efficiency (E_f, %) of LCH,

$$E_{f\,1} = \frac{1530 - 305}{1530} \times 100 = 80.06\%$$

$$E_{f\,2} = \frac{1770 - 335}{1770} \times 100 = 81.07\%$$

$$E_{f\,3} = \frac{1680 - 353}{1680} \times 100 = 78.99\%$$

∴Average Field efficiency of LCH=80.04%.

So, Field efficiency (E_f, %) of MCH,

$$E_{f\,1} = \frac{540 - 70}{540} \times 100 \quad = 87.04\%$$

$$E_{f\,2} = \frac{480 - 65}{480} \times 100 \quad = 86.46\%$$

$$E_{f\,3} = \frac{480 - 63}{480} \times 100 \quad = 86.875\%$$

∴Average Field efficiency of MCH= 86.79%.

So, Field efficiency (E_f, %) of Manual harvesting,

$$E_f = \frac{480 - 130}{480} \times 100 \quad = 72.92\%$$

Effective field capacity (EFC, ha/hr) calculation:

We know,

Effective field capacity (EFC, ha/hr) = $\frac{SwE_f}{10}$

Where,

EFC= Effective field capacity (ha/hr)

S=forward speed (km/hr)

w= width (m)

E_f=field efficiency (%)

∴ Effective field capacity (EFC, ha/hr) of LCH = $\frac{3.112\times2.477\times0.8004}{10}$

= 0.617 ha/hr.

∴ Effective field capacity (EFC, ha/hr) of MCH = $\frac{3.375\times1.283\times0.86875}{10}$

= 0.376ha/hr.

Effective field capacity of manual method:

2 labour can harvest in 1 day or 8 hrs= 667.32 m^2

1 labour can harvest in 1hr=41.71 m^2

∴ Effective field capacity of manual method= 0.0042 ha/hr.

Again labour required for harvesting per ha = $\frac{2\times10000}{667.32}$

=29.97

≅30 labour/ha

Harvesting losses (%) calculation:

Harvesting losses include shattering and uncut losses and threshing losses were determined by the following equation:

$$Wgt = Wg1 + Wg2 + Wg3$$

Where,

Wgt= total losses (g/m^2)

Wg1= shattering losses (g/m^2)

Wg2= cutter bar losses (g/m^2)

Wg3 = threshing losses (g/m^2)

∴Total losses of LCH,

W_{gt}=12.58+5.95+7.67 (from losses Table-4.4)

=26.2 g/m^2

∴Total losses of MCH,

W_{gt}=9.92+6.30+6.78 (from losses Table-4.4)

=23 g/m^2

Now we know,

Losses percentage, $H = W_{gt}/Y_g \times 100$

Where,

H= percentage of harvest losses (%)

Y_g= grain yield (g/m^2)

W_{gt} = threshing losses (g/m^2)

∴Losses percentage of LCH= $\frac{26.2}{750} \times 100$ =3.49%

∴Losses percentage of MCH= $\frac{23}{750} \times 100$ =3.066%

APPENDIX- 2

Cost determination

Cost of large combine harvester (LCH):

Here,

New price, P= 4000000 Tk

Salvage value, S= 10% of P

$=0.1\times4000000=$ 400000 Tk

Interest, i=13%

Fuel price=70Tk/lit

Yearly use= 60 day/yr

Daily use= 8 hr/day.

Fuel consumption=15.58 lit/hr

Fixed price:

Depreciation, D= $\frac{P-S}{L}$

$=\frac{4000000-400000}{10}$

=360000 Tk/yr.

Interest on Investment, IOI= $\frac{P+S}{2}\times i$

$=\frac{4000000+400000}{2}\times 0.13$

=286000 Tk/yr.

Tax, insurance & shelter, TIS= 2% of P

$=0.02\times 4000000$

=80000 Tk/yr.

Total fixed cost =360000+286000+80000

=726000 Tk/yr.

Fixed cost per hour= $\frac{726000}{60\times 8}$

=1512.5Tk/hr.

Variable cost:

Repair & maintenance cost, R&M=0.025% of P

$=0.00025\times4000000$

=1000 Tk/hr

Fuel cost=15.58×70=1090.6 Tk/hr

Oil cost= 15% of fuel cost

=0.15×1090.6=163.59 Tk/hr

Labour cost per hour= $\frac{1000\times1+500\times4}{8}$ = 375Tk/hr.

Total variable cost=1000+1090.6+163.59+375

=2629.19Tk/hr.

∴ Total cost= 1512.5 + 2629.19= 4141.59Tk/hr.

∴ Operational cost= $\frac{\text{total cost}\left(\text{Tk / hr}\right)}{\text{effective field capacity}\left(\text{ha / hr}\right)}$

$= \frac{4141.19\ \left(\text{Tk / hr}\right)}{0.6169\left(\text{ha / hr}\right)}$

= 6712.903Tk/ha.

=6713 Tk/ha.

Cost of medium combine harvester (MCH):

Here,

New price, P= 1800000 Tk

Salvage value, S= 10% of P

$=0.1\times 1800000$= 180000 Tk

Interest, i=13%

Fuel price=70 Tk/lit

Yearly use= 60 day/yr

Daily use= 8 hr/day.

Fuel consumption=8.83 lit/hr

Fixed price:

Depreciation, $D = \frac{P-S}{L}$

$= \frac{1800000-180000}{10}$

=162000 Tk/yr.

Interest on Investment, IOI= $\frac{P+S}{2}\times i$

$= \frac{1800000+180000}{2}\times .13$

=128700 Tk/yr.

Tax, insurance & shelter, TIS= 2% of P

$=0.02\times 1800000$

=36000 Tk/yr.

Total fixed cost=162000+128700+36000

=326700 Tk/yr.

Fixed cost per hour= $\frac{326700}{60\times 8}$

= 680.625Tk/hr.

Variable cost:

Repair & maintenance cost, R&M=0.025% of P

$=0.00025\times1800000$

=450 Tk/hr

Fuel cost=8.83×70=618.1 Tk/hr

Oil cost= 15% of fuel cost

=0.15×618.1 =92.715 Tk/hr

Labour cost per hour=$\frac{700\times1+500\times3}{8}$= 275 Tk/hr.

Total variable cost=450+618.1+92.715+275

=1435.815Tk/hr.

∴Total cost= 680.625 + 1435.815 = 2116.44 Tk/hr.

$$\therefore \text{Operational cost}=\frac{\text{total cost}\left(\text{Tk / hr}\right)}{\text{effective field capacity}\left(\text{ha / hr}\right)}$$

$$=\frac{2116.44\left(\text{Tk / hr}\right)}{0.3762\left(\text{ha / hr}\right)}$$

= 5625.837Tk/ha.

=5626 Tk/ha.

Cost of manual harvesting method:

In manual method, labour required per ha= 30

Wage of each labour= 500 Tk/day

So manual harvesting cost= 30×500

=15000 Tk/ ha.