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# APPROPRIATE SCALE AND BUSINESS VIABLE WHOLE FEED COMBINE HARVESTER FOR SUSTAINABLE AGRICULTURAL MECHANIZATION IN BANGLADESH

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## ABSTRACT

The soil and topography of Bangladesh are distinct from other countries. As a result, not all imported machine models work effectively here. Bangladesh needs to develop combine harvesters that are technically, environmentally, and economically viable. Thus, a research platform for locally acceptable combine harvesters was established by comparing the techno-economic performance of three imported harvesters in haor districts. The Chinese (4LZ-0.6), Sifang (4LZ-1.5), and Zoomlion (4LZT-4.0ZD) models with a cutting width of 1000, 1500, and 2000 mm, respectively, were employed in this study. The harvesting capacity, fuel consumption, harvesting loss, minimum suitable plot area, ground pressure, business viability, transportation, and operator comfortless were considered to recommend a suitable machine. Based on the result, Zoomlion model whole feed combine harvester is excellent for harvesting in the haor area in the bigger sizes plot, while a head width of 1500mm for smaller plots. While a small combine's cost is incredibly low, farmers have refused to adopt the equipment since their businesses have failed because of its restricted harvesting capacity and high component failure rate. The machinery must be transportable in a conventional truck due to the remote road conditions (truck width 2000 mm). As a result, local roadways can accommodate whole feed combine harvesters with an 1800 mm width. In haor regions, 24 kNm-2 ground pressure and 300 mm ground clearance functioned effectively. The adjustment of the harvester machine is extremely subtle, resulting in strong vibrations in a single cylinder engine, causing parts to fail prematurely and the driver to be unable to operate the machine comfortably for extended periods of time. As a result, four-cylinder engines outperform one-cylinder engines in popularity. Access to machine components is critical, as is the presence of a grain tank for simple supply.

**Keywords:** Design criteria, Ground clearance, Ground pressure, Maneuverability, Vibration.

## 1. INTRODUCTION

Bangladeshis rely heavily on rice as their primary food source. Its production contributes significantly to the combat against food shortages and the development of domestic and international food security. It is critical to harvest paddy on time to minimize output losses. Due to the lack of a mechanical harvesting system, considerable field losses of paddy occur each year

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as a result of natural disasters and a lack of harvesting time [1]. Due to manpower shortages and high labor wages, timely harvesting of paddy is a major concern currently. Nonetheless, data suggests that rural labor supply is dwindling as workers travel to cities or abroad in search of more lucrative jobs, particularly in the garment and construction industries [2]. Agriculture accounts for around 13.82 % of the Gross Domestic Product (GDP) of the country and employs more than 45% of the entire work force [3].

Farmers are having difficult time harvesting rice because of a scarcity of field workers and natural disasters that have struck the area. In Bangladesh, harvesting still requires a lot of manual labor. There isn't enough labor to meet both of these requirements at that moment. It's also worth noting that Bangladesh's cropland availability has decreased by 68,760 ha per year (0.73%) since 1976, indicating that further expansion of agricultural land is unlikely [4]. Bangladesh must increase food production on the same land while also facilitating more lucrative alternatives to farm labor [2]. More than 90% of rice crop is harvested by hand sickle. It is then threshed and cleaned by thresher or power tiller. At least 100-150 persons are needed to harvest a single hectare of rice field in one hour using manual harvesting methods [5]. In comparison to manual harvesting, using a combine harvester required 34% more work [6]. Combine harvesters, according to [7], are energy efficient, labor and time saving machines, but their initial purchase price is prohibitive. To maximize output while minimizing crop losses, damage, and machine upkeep and repair expenses, a high-tech combine harvester is required [8]. Field size, field-to-field distance, machine accessibility, crop attributes, combine harvester preparedness and management as well as economic factors all have a role in a combine harvester's performance [9]. A crop's harvesting yield, nutritional value, and production costs are all influenced by the equipment size and type employed [10]. It is recommended that a combine harvester be operated at the lowest feasible cost to achieve optimal efficiency [11]. To adapt and promote an adequate scale of mechanical harvesting in Bangladesh, a business-viable combine harvester is needed. In this region, several research have been done on the economic and technical performance of combine harvesters [7-12-13-14-15]. Field response (capacity, efficiency, maneuverability, harvesting loss, vibration and noise, etc.) and time distribution in harvesting operations on various farm sizes were studied in the previous research. A lack of research pushed us to create design criteria and the research background for a locally appropriate combine harvester. Researchers, policymakers, extension workers, and other relevant actors and users will benefit greatly from the outcomes of this research.

## 2. MATERIALS AND METHODS

### Study location

This research was completed between March and May 2020, in Maisherkandi, Mithamain upazila, Kishorganj district (Figure 1). About 37 hectare of paddy were harvested in 214 different sizes of plots by employing three models of combine harvesters, which were chosen for their ability to harvest the high, rice BRRI dhan29. In the *haor* basin, soft and muddy land with a water surface of 25 mm was typical during rice harvesting. The soil conditions of most of the places were sandy loam and data was collected from selected paddy fields in 18 places.

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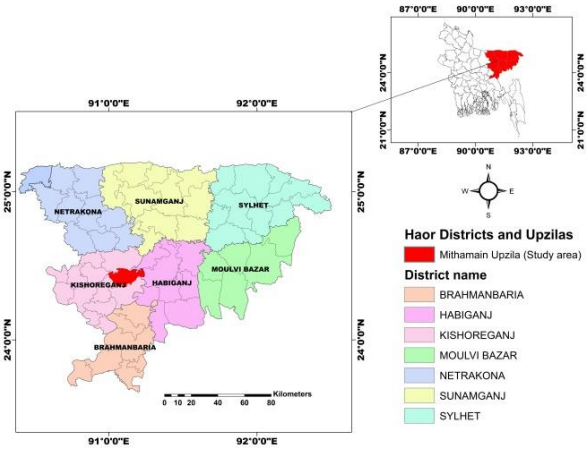


**Figure 1.** The study location of combine harvester

**Combine harvester**

SCH (Small Combine Harvester), MCH (Medium Combine Harvester) and LCH (Large Combine Harvester) harvesters were employed in this investigation. Chinese 4LZ-0.6; Sifang 4LZ-1.5; and Zoomlion 4LZT-40 ZD were used to represent SCH, MCH, and LCH combine models, as illustrated in Figure 2. The features and characteristics of various types of combine harvesters are listed in Table 1.

(a) Small combine harvester

(b) Sifang combine harvester


(c) Zoomlion combine harvester

**Figure 2.** Field operation of imported combine harvester

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**Table 1 Specification of imported combine harvesters**

| Brand name | Chinese | Sifang | Zoomlion |
|---|---|---|---|
| Model | 4LZ-0.6 | 4LZ-1.5 | 4LZT-4.0ZD |
| Portable Harvester Type | Mini Combine Harvester | Whole Feed Creeper Self-Propelled Type | Whole Feed Creeper Self-Propelled Type |
| Engine power, kW/rpm | 6.6/2600 | 24/2200 | 70/2400 |
| Engine type | Single cylinder | Single cylinder | Four-cylinder water cooling diesel engine |
| Outer dimensions, mm | 2700×1380×1300 | 4000×2000×2200 | 5270×2300×2960 |
| Cutting width, mm | 1000 | 1500 | 2000 |
| Rubber track (Crawler) | 255×80×30 | 320×90×40 | 400×90×52 |
| Ground clearance, mm | 200 | 200 | 325 |
| Weight, kg | 268 | 1500 | 3260 |

**Performance evaluation of combine harvester**

Field capacity (Theoretical and actual), efficiency, operational speed, working hour and fuel utilization are considered as performance parameters during field operation. Field efficiency is measured using Eq. (3) which denoted the proportion between the productivity of a harvester under actual working conditions and the most conceivable productivity in theory.
[16].

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

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

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

After harvesting, a measuring container was used to refill the combine's fuel container to its full capacity. Using a sophisticated stopwatch, we were able to record time data that included both the effective (or actual harvesting operational) and turning (or turning and reversing) times, as well as any additional time spent by the combine harvesters (operators time - machine setting or maintaining). The average time is calculated by dividing the total time spent on the farm by the number of farms. A stopwatch was used to record harvesting time, and a measuring tape was used to measure line length. The average harvesting speed was calculated by summing the harvesting speeds of all lines and dividing the result by the total number of lines. A standardized questionnaire was used to collect feedback from combine harvester users and operators on the machine's performance. KII (Key Informant Interviews) confirmed that the comments were genuine. Experiment results were analyzed and presented in a tabular and graphical format using MS-Excel 2013.

## 4.RESULTS AND DISCUSSION

**Engine power**

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High vibration and low power are the hallmarks of a single-cylinder engine; increasing the number of cylinders results in better power and higher fuel consumption, but vibration is reduced. Chinese and Sifang combine harvesters use a single-cylinder engine, which consumes less gasoline but is less comfortable because of higher parts failure frequency and less operator-friendly because of excessive noise and vibration. On the other hand, the Zoomlion model features a four-cylinder engine that consumes more fuel but generates less vibration and noise, making it more operator-friendly. Therefore, harvesting crops necessitates a machine with a four-cylinder engine.

**Ground pressure**

In Bangladesh, the soil is soft at harvesting time. Especially in Boro Season, the soil is softer due to heavy rainfall. When the harvester goes to work in the soft land, the mud goes to the ground. Machine can produce ground pressure depends on the size of the harvester track. High harvester weight results in punching holes into the ground, making it possible to choose an optimal track for maximum load with minimal ground pressure. Due to low weight, the Chinese combine and Sifang model combine harvesters have chosen the smallest crawler size. The harvester model Zoomlion was equipped with a wide crawler and high weight. The objective is to keep the contact pressure below a threshold value, which will ensure effective operation in silty to clay-textured soils with a high moisture content or even standing water. According to research, a combine harvester can generate up to 24 $kNm^{-2}$ ground pressure in Bangladeshi land [17].

**Cutting width**

The rated power of a combine is connected in part to the width of its cutter bar, as a wider cutter bar requires more power to chop and process the crop. If the cutting width is more, the harvesting capacity of large combine in small plots in Bangladesh will remain in unused. Due to the small working width, the harvester is easy to transport and operate. The small cutting width is suitable for turning in the smallest land areas with moderate forward speed and transport under normal truck loads. Therefore, Chinese combine and Sifang combine harvester poor technical and economic performance, suitable for local conditions, but inconvenient for users, and model Zoomlion is suitable in larger size of land. Hence, 1800 mm wide whole feed combine harvester is easily accessible for local road.

**Optimum Plot area**

Bangladesh has own small plots of land in isolated places. Cutting width of harvester, the less and it is the easier to operate the machine in minimum plot area. If the plot area for machine is suitable, it can easily take turns, thus increasing the harvesting capacity of the machine. The minimum plot area requirement for model's Chinese, Sifang, and Zoomlion increases as the cutting width increases, where the machine having 1800 mm overall width can operate in 500 $m^2$ plots.

**Harvesting capacity**

In order to maximize harvesting capacity, it is necessary to optimize the machine's cutting width and operating speed. The harvest capacity of the machine was dependent on the size of the field. If you want to get the most out of your combine harvester, you need to choose your crop fields wisely. Table 2 shows that the field area required for Chinese, Sifang, and Zoomlion model

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combine harvesters is 400, 500, and 800 $m^2$. Chinese and Sifang combine harvesters have low harvesting capability, with a range of 270-470 and 870-1340 $m^2$ $h^{-1}$, respectively while Zoomlion model capacity is 2675-5350$m^2h^{-1}$. The harvesting capability of the combine harvesters was deemed inadequate by farmers. Due to its increased harvesting capacity, however, farmers expressed satisfaction.

**Table 2 Comparative performance of combine harvester**

| Brand name | Chinese | Sifang | Zoomlion |
|---|---|---|---|
| Price, USD | 5800 | 12000 | 26000 |
| Normal-sized truck load | Yes | Yes | No |
| Ground pressure, kN $m^{-2}$ | 5 | 20 | 24 |
| Forward speed, km $h^{-1}$ | 0.63-0.90 | 1.40-1.90 | 1.23-3.20 |
| Fuel required, L $h^{-1}$ | 0.8-1.2 | 2.04 | 4.8 |
| Total harvesting loss, % | 1.12-1.40 % | 1.50-2.13% | 1.60-1.91% |
| Minimum suitable plot area, $m^2$ | 400 | 500 | 800 |
| Harvesting capacity, $m^2$ $h^{-1}$ | 270-470 | 870-1340 | 2675-5350 |

Note: 1 USD = BDT 86.0

**Grain collection system**

Grain from combine harvesters in Chicness and Sifang was delivered directly to bags. Harvested grain was kept in the tank for later unloading in the combine harvester of Zoomlion, which was used to harvest wheat. The equipment must include a grain tank for convenient delivery in muck terrain, according to the instructions. Combine harvesters now in use in Bangladesh are either equipped with a grain tank with a capacity of 600 kg or have a bag-filling capacity. Bag-filling machines require an additional operator (which increases the machine's weight) and drop filled bags into the field to be collected after crop harvest. This is less handy than tank-type combines that collect grain for loading into bags or trucks. Therefore, combine harvester equipped with grain tank is more preferable by the farmers.

**Grain cleaning**

Cleaning mechanisms in both the Chinese combine harvester and the Sifang combine harvester functioned flawlessly. A cyclone separator was used to successfully clean the grains, delivering more than 95% of the cleaned grain. A blower is attached to the Zoomlion combine harvester to clean the grain, and it works perfectly. As a result, each farmer was delighted with the grain cleaning technology.

**Threshing loss**

Grain spillage, insufficient grain separation from chaff, and grain breakage as a result of excessive striking all contribute to grain losses during threshing. Farmers reported no major grain damage caused by the Chinese combine harvester. In Sifang and Zoomlion, just a little amount of unthreshed grain was observed, which met farmer demand.

**Status of straw after harvesting**

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After harvesting, the straws were trimmed. It seemed to everyone that straw could be stored for a lengthy period once it was harvested by the combine harvester. Despite this, straw must be in an uncut state following threshing.

**Vibration and noise**

Due to the usage of a single cylinder engine, the vibration behaviors of several structures are more pronounced in Chinese and Sifang type combine harvesters. Vibration is present at the harvester's header component, which is triggered by the load and the roadway surface. Due to the vibration and noise generated by the cutting component, the driver's comfort and the life of the entire frame are reduced. Due to vibration, nuts and bolts were loosened. The operator was uneasy due to the machine's vibration. This unsettling level of vibration increases human drudgery, which has a significant impact on the ability to operate the combine harvester for an extended period during paddy harvesting seasons. However, vibration and noise levels are within the operator's tolerance range when operating the Zoomlion harvester.

**Maneuverability**

The operator's comfort of operation is impeded by the seating design and the gear transmission mechanism, which is not the operator's friendly in Chinese and Sifang combine harvester. However, in Zoomlion combine harvester, gear shifting mechanism is operator’s friendly.

**Business viability**

The economic analysis of combine harvester was done considering following cost assumptions. Farmers can afford them because the Chinese and Sifang models are cheaper. However, those machines are not business viable due to its low capacity and high parts failure frequency. On the other hand, purchase price of the Zoomlion is higher than other two models. It is accepted by farmers and appeared as business viable machine due to high harvesting capacity and operator’s friendly. Both entrepreneur and farmers benefitted by using this machine on rental system. The government subsidy program is encouraging the widespread adoption of large-scale machines. Islam (2021) stated that mechanized harvesting saved 40% harvesting cost, 90% time and 80% manpower. The payback of period of the Zoomlion combine harvester would be 2-3 yrs if entrepreneur purchased harvester at 70% subsidy price in *haor* areas (Islam, 2021).

**Plot to plot movement**

Bangladesh has small plots of land in remote areas. Due to the lower size of Chinese and Sifang combine harvesters, operators reported no difficulty transferring machines between plots. However, operators encountered difficulties transferring plots because to the increasing size of harvesters such as Zoomlion. A whole feed combine harvester with a cutting width of 1500 mm is suitable for harvesting existing plots and moving from plot to plot.

**Parts availability**

There are no replacement parts accessible any closer to the rice field. Located far from rice fields, the machine components market has a limited supply. An operator must keep a supply of the most vulnerable parts on hand in order to prevent downtime.

**Machinery carrying**

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In the rural road condition normal truck can move in rural road. The width of normal truck is 2000 mm. The machine having 1800 mm width can easily transport in normal truck.

**Operators' comments**

Due to the smaller size of the harvester, there is no difficulty lifting it from plot to road, and operators have no difficulty transferring it between plots. However, due to strong vibrations and noise, operators do not feel comfortable operating the harvester produced by Chinese and Sifang combine harvesters. Alternatively, the operator's ease of operation was aided by the seating configuration in Zoomlion model. Operators reported a sense of security when operating the Zoomlion harvester. Due to the machine's in-built good lighting settings, it can also be operated at night.

**Farmer's comment**

Grain damage was observed in three model of combine harvester. After harvesting the chopped straw lay in the field. Every farmer thinks that he can keep straw from the combine harvester for a long time. Harvesting capacity is very low in Chinese and Sifang model combine harvester. Farmers have expressed dissatisfaction with the Chinese combine harvester and Sifang model's capability to harvest. They wanted machine having higher harvesting capacity. Farmers showed satisfaction on the performance of Zoomlion model due to higher harvesting capacity. On the other hand, farmers have expressed satisfaction with Zoomlion model due to the availability of storage tanks. The unloading operation was carried out at a place near the field and harvesting capacity is high. The harvesters must have grain tank to maximize the harvesting performance.

**Overall comments**

The Chinese combine harvester is suited for small parcels of land that larger equipment is unable to access. Farmers, on the other hand, expressed happiness with the Sifang and Zoomlion combine harvesters as a result of the economic benefits.

**Design criteria of combine harvester suitable for Bangladesh**

- The 2200 mm overall width whole feed combine harvester is suitable for *haor* areas due to larger land sizes.
- The 1800 mm overall width whole feed combine harvester is suitable for other areas.
- Farmers do not like small size machines because of low harvesting capacity.
- Must be transportable in a normal truck (truck width 2000 mm).
- Ground pressure will be less than 24 kN $m^{-2}$.
- The ground clearance will be 300 mm.
- The adjustment of the harvester machine is very subtle resulting in a high vibration in a single cylinder engine which causes the parts to break down very quickly and the driver cannot operate the machine comfortably for long. Four-cylinder engines suitable instead of single cylinder engine
- The machine must have a grain tank for easy delivery
- Machine parts must be readily available.

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## 5. CONCLUSION

Chinese combine harvesters are perfect for little plots of land that are inaccessible to larger machines. This would enable small business owners to choose from a variety of mechanized alternatives for paddy harvesting, thereby encouraging the future adoption of improved technology. Whereas with the Sifang model, grains were lost during the cut crop harvesting process due to the header unit's insufficient inclination. To achieve the desired performance, the power supply system must be modified. Chinese and Sifang type combine harvesters were not operator friendly due to significant vibration and noise. Furthermore, component failure rates are significant, and harvesting capacity is highly limited. As a result, two combine harvesters have been designed that are acceptable for local conditions but are lacking in technical and economic performance and cumbersome for users. Vibration and noise levels were found to be within the operator's tolerable range when compared to the Zoomlion model. The operator discovered the machine to be quite straightforward to operate. This machine is ideal for use in muddy fields with a water depth of 40-80 mm, has exceptional technical and economic performance, and is exceptionally user-friendly. However, due to its massive size, this machine is not widely accepted in our present land tenure system.

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**Conflicts of Interest**

The authors declare no conflicts of interest regarding the publication of this paper.

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