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Economic Worth Assessment of Implementing Baler Technology for the Management of Paddy Straw

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Abstract

Mechanical collection of paddy straw with the help of the baler technology from the combine harvested paddy fields is a prevalent paddy straw management technique in the country. Baler technology manages the paddy straw by collecting it with the rectangular baler, rake and stubble shaver machines and preventing the on-farm paddy straw from burning. Finding the financial constraints for creating a tailored recruiting system for technology implementation at the field level in paddy straw management was one of the main goals of this study. The economic worth assessment showed that the total operating cost for systems I and II was estimated as ₹ 4285.74 and 2374.34 per hour and the net benefit was ₹ 998.09 and 991.16 per hour. The benefit-cost ratio of the system I and II of baler technology was found to be 1.23 and 1.42 and the break-even usage of the baler technology was assessed at 154.66 and 109.65 hours per year of machine operation, which is less than the machine's useful life used under baler technology implementation. Hence, machine owners, local service providers (LSPs) and forward-thinking farmers can seize this opportunity as a highly lucrative endeavour. Steering clear of on-farm burning of paddy straw is a crucial step toward reducing environmental pollution, making it a worthwhile contribution to environmental conservation.

Keywords: Baler, Break-Even Point, Burning, Cost, Paddy, Payback Period.

Introduction

Globally, India has the largest area (44.6M ha) under paddy and is second only to China in paddy production. Paddy constitutes 52 per cent of food grain production and 55 per cent of total cereal production (Hira *et al.,* 2015). Paddy-wheat cultivation is a common farming exercise in northern Indian region. India produces 117 Mt paddy per year and such a vast amount generates 185-200 Mt paddy straw. Twenty-five per cent of Asia's total paddy straw production comes from India (Bhuvaneshwari *et al.,* 2019). The states of Haryana and Punjab are recognized as India›s "food bowl" because they contain a highly fertile paddy-wheat area on the Indo-Gangetic plain. Only in Punjab are paddy and wheat cultivated in more than three and 3.5 million hectares of land, with about 22 million tonnes of paddy residue per year (Mander, 2018).

Residues from paddy crops consist of biomass remaining in the field following grain harvesting and other valuable elements. As a byproduct of harvesting rice, paddy straw is created. Irrespective of whether it was harvested manually or by machinery, it is taken out during harvest with the rice grains and then stacked up or scattered across the field. As labour costs rise and rice production intensifies in Asia, combine harvesters are becoming more common in rice fields during harvest season. However, the loose rice straw left behind by these machines complicates the collection and transportation process, resulting in increased expenses and time requirements. Asia annually generates between 600 to 800 million tons of rice straw, with global production nearing 1 billion tons each year (Sarkar and Aikat, 2013; McLaughlin *et al*., 2016). Farmers chose to burn rice straw as a fast fix to swiftly eliminate the biomass and get the field ready for the forthcoming crop since they are unaware of the straw's other uses. Burning rice straw in the field poses risks to both human health and the environment, leading to increased greenhouse gas emissions. For every kilogram of dry rice straw burned, emissions of 0.7 to 4.1 grams of CH_4 and 0.019 to 0.057 grams of N_2O occur, along with additional gaseous pollutants such as SO2 and NOx. Additionally, though to a lesser extent, the burning process also releases dioxins and furans (Oanh *et al*., 2011; Jenkins *et al*., 2003). Burning rice straw serves as a crucial origin of aerosol particles, impacting both local air quality and the Earth's radiation balance (Engling *et al*., 2009). These particles include small dust particles ($PM_{2.5}$) and coarse dusty particles (PM_{10}) (Chang *et al.,* 2013). Furthermore, biomass loses its potential energy content (Tabil *et al*., 2011). Ozone levels in the lower atmosphere are also raised by burning agricultural crop residue (Kumar *et al*., 2015). Burning agricultural leftovers raised soil temperatures to 33.8-42.2 °C to a depth of 1 cm, as Gupta *et al*., (2004) reported. This has an impact on soil ecology. Thus, due to the increased soil temperature, the favourable microbial population in the soil decreases to a depth of 2.5 cm and around 23-73% of the nitrogen in different kinds is taken from the soil. The burning of residue raises the soil's temperature considerably, which causes the upper three inches of the soil's carbon-nitrogen (C-N) balance to shift quickly. Nitrogen transforms into nitrate, while carbon is emitted into the environment as CO_2. Approximately 824 thousand metric tons of nutrients-nitrogen, potassium and phosphorus-are lost from the soil due to this process (Gupta *et al*., 2004). Two more approaches to controlling paddy straw are baling the straw and integrating it into the field, in addition to infield burning (Singh *et al.,* 2005).

Rice straw management and collecting continue to be challenging tasks. In the past, several methods have been experimented with for collecting and managing rice straw. These include field cubers, stack wagons, buck rakes, standard three-wire balers, traditional large roll balers and high-flotation big roll balers, were documented by Dobie *et al*., (1977). Dobie concluded that, for a 16 km haul distance, the most economical system to be provided would be a 1.2 m comprehensive extended roll baler system. Though he had yet to test a big rectangular baler, Dobie (1980) also suggested that a substantial rectangular bale system would be more promising than the massive roll bale system. Rice straws should be gathered and used to provide electricity or be subject to alternative management alternatives for financial and environmental reasons. For individuals looking to develop a cost-effective structure using sustainable materials, straw bale construction may be one of the greatest options (Bhattarai *et al*., 2012).

A big rectangular baler for gathering rice straw was tested by Jenkins *et al.,* (1985). The performance of balers was contrasted with that of alternative handling methods and large roll balers. Economically speaking, large bale systems are preferable to tiny, rectangular bale systems. Big rectangular bales worked well for transportation, but they needed to be stored under cover to prevent spoiling. Large roll bales may be stored outside without losing much dry matter, although they were less popular for long-distance transportation. Straw delivery costs vary depending on the kind of packaging, distance travelled, necessary processing steps and method of use. Timely use of the field for following planting, collecting and baling paddy straw in the combined harvested field is a suitable and financially feasible solution (Tathod *et al*., 2015). The economic and environmental performance of straw baler (Model 338 make: John Deere), for the collection of paddy straw generated after mechanical harvesting by combine harvester was determined by Pal *et al.,* (2019). Straw baler facilitated the collection of paddy straw of 4.36 tons/ha at a cost of just ₹1650. Nghi *et al*., (2015) conducted experiments which revealed an internal rate of return of 38%, a payback period of 2.1 years and a baling cost of US$ 19.0 per ton of rice straw. Along with the baling fee, the transportation cost ranges from US$24 for a 100-kilometer journey to US$32 for a 150-kilometer distance. In 2013, Shafie *et al.,* undertook a logistic cost analysis focusing on rice-straw-based power generation in Malaysia. They developed mathematical logistic models to assess the collection, storage and transportation costs associated with this form of power generation. The ideal quantity of storage facilities and the location of the power plant were determined using the optimization approach. According to the results, the transportation expenses for conveying rice straws to collection centres primarily stemmed from the influence of truck capacity, constituting 89.9% of the total expenditure in transportation. Transportation costs were also the highest, accounting for 54% to 63% of the overall logistic costs. The number of storage facilities might be decreased to lower the cost of transportation.

The baler has been introduced in India to recover straw from the combined harvested paddy field. Baler machine owners have the option to utilize their equipment on their own land and also generate revenue by offering custom hiring services to fellow farmers. Sharma and Chandel (2016) assess a baler's performance on loose paddy straw (system A) after the use of a stubble shaver (system B) and following the use of a rake in addition to the stubble shaver (system C). When the feed rate of paddy straw rose from 1.12 to 4.22 tonne per hour, the number of bales per hectare and density of bales also increased. The maximum feed rate was seen when the stubble shaver and rake were used before the baler (system C). Systems A, B and C had field capacities of 0.35, 0.40 and 0.53 ha per hour and ranged in the number of bales per ha from 266-292, 298-332 and 126-149, respectively. For systems A, B and C, the corresponding mean fuel consumption was 5.0, 10.0 and 12.0 litre per hour. System C had a more significant mean per centage increase in bale density, quantity of bales and baler productivity than did systems A and B. System C had the highest benefit-cost ratio at 1.16:1, while systems B and A had the highest ratios at 1.06:1 and 0.85:1, respectively. With systems B and C, the net savings per hectare were Rs. 471.05 and 1537.59, respectively. The economic and practical effectiveness of a straw baler in a combine-harvested rice field is assessed by Singh *et al*., (2005). In the paddy field harvested by a combine, the baler's field capacity was 0.26 ha per hour; however, in the field where the stubble shaver was used before baling, it was 0.36 ha per hour. Bales ranged in size from 800×450×450 to 900×450×450 mm and correspondingly, their weight varied between 18 and 28 kg. In combine-harvested paddy fields, 205 bales were made; in stubble-shaved paddy fields, 425 bales were formed. The straw baler's economic analysis showed that baling in fields with stubble shaved fields costs Rs. 2276 per hectare, while transporting the bales costs Rs. 4400 per hectare. Baling in stubble-shaved fields costs Rs. 6676 per hectare, including bale transportation. The machine's extremely high shipping cost is the single factor keeping it from becoming more widely used. Straw sales brought in a total of Rs. 5865 per hectare. According to Mangaraj & Kulkarni's (2011) research, the cost of making a single twine-tied bale for wheat and paddy was ₹ 5.00 and ₹ 2.75, respectively. The net income from collecting and baling straw using the machine was ₹ 607.00 per hectare for rice straw and, ₹ 235.00 per hectare for wheat straw, assuming nominal prices of ₹ 0.25 kg^{-1} for paddy straw and ₹ 0.75 kg^{-1} for wheat straw. Not all of the villages in the area have had access to baler technology yet. Baler technology service providers, or new entrepreneurs, may get started and have a great potential to offer this service to end users nearly all year round. For this purpose, from the owner or custom operator's point of view, the economic worth assessment of baler technology is a dire need. Therefore, determining critical indicators related to the economic worth assessment of baler technology used by the service providers/progressive farmers to manage (collect) paddy straw is the need of the hour. So, the present study assessed the economic worth of baler technology implemented for managing paddy straw by its mechanical collection.

Materials and Methods

Data collection

The study was conducted in the district Moga of Punjab in India. Moga district is located in the central zone of the state, having a plain geographical area of 2230 sq. km., which comes to 4.42 per cent of Punjab state. It stretches between 75 degrees 15'E and 75 degrees 25' E longitude and 30 degrees 35' N and 31 degrees 15' N latitude. Farmers in the Moga district primarily rotate their crops using paddy wheat. The district of Moga is expected to have 195,237 hectares of total agricultural land, of which 176,000 hectares (91.27%) are under rice cultivation and 175,000 hectares (89.63%) are under wheat crop cultivation. In this study, secondary data were gathered from a variety of sources. Studies journals, published studies, progressive farmers and machine owners/operators served as the primary sources of data. Using an information panel, several crucial operational data were gathered from primary sources and research on baler technology.

Baler technology

The baling process, a common automated technique for gathering hay, straw and other fibrous materials through densification, uses baler technology. This process effectively facilitates the removal of materials from the field, simplifies the transportation and manipulation of bales, addresses shortages and provides flexibility in storage options. (Van-Hung *et al*., 2016; Guerrieri *et al*., 2019; Lemos *et al*., 2014). This mechanical process of collecting straw is performed with the help of tractor-operated machinery. It requires three tractor-driven machines: a stubble shaver for cutting, a rake for lining and gathering and a baler for making bales.

Stubble shaver

Paddy stubble was trimmed with a stubble shaver when it was standing. The machine operates in 2nd low gear, maintaining engine rpm between 1500 and 1700, which can vary depending on the load of paddy straw. It features two blades mounted on a vertical shaft, enclosed within a frame on the top and all four sides. Through a gearbox, a tractor's PTO (power take-off) shaft rotates the shaft.

Rake

Following the stubble shaver's operation, leftover straw can be gathered in a small breadth with a tractor-driven rake equipment that needs between 40 and 50 horsepower (hp) of power. The rotating rake has a working width of 3.5 meters and a transport width of 1.5 meters. It weighs between 350 and 450 kg. The rake's job is to gather loose and chopped paddy straw from the field and create a windrow in the smaller area so that the baler machine has thick straw to work with.

Adjusting to the load of paddy straw, this machine is frequently operated in third low gear, maintaining engine RPMs between 1500 and 1700.

Straw Baler

In the present study, a rectangular baler was considered which picks up a pre-cut crop from a windrow and feeds it into the bale chamber, where it is cut again, compacted, tied and discharged out the back of the machine. It has the ability to regulate the bale density and level of compaction. The machine also has a measuring system for changing the bale length. The hypoid gear, which had spiral interactions between the crown wheel and pinions, served as the baler's main drive (**Figure 1**). This had the benefit of having a larger gear tooth contact area than with conventional gear meshing, which increased longevity and consistent power flow (Sharma and Chandel, 2016). In order to ensure smooth operation of the baler, a broad flywheel was installed in front of the transmission system to absorb the stresses of the ram. Depending on the amount of paddy straw, the baler was run in 2nd low gear in the current investigation, with engine rpm ranging from 1500 to 1800.

Mechanical operation of bale formation

Initially, the stubble shaver machine is employed to harvest the stubbles, left in the field subsequent to combine harvesting of the paddy, from the base level. Subsequently, the lining operation is executed by the rake machine, followed by the gathering and formation of rectangular bales by the baler. It automatically picks up the straw from the field with the help of a reel and transfers it into the bale chamber with the help of a feeder and then the straw is compressed with the reciprocating ram. Straw baler made highly compressed, firm and perfectly shaped bales (**Figure 1**), reducing the storage space (Sharma *et al*., 2014). All these machines are commercially available and can be operated by the 40-50 hp tractor.

Figure 1: Operational view of rake and baler machine

Economic assessment of baler technology for managing paddy straw

The economic assessment of agricultural systems is necessary to understand peasant practices and create and disseminate innovative systems. Agricultural machinery costs assessment is critical when considering structural or technological changes. Because the advantages and costs of machinery investments in agriculture accumulate over a number of years, it is more complicated than dealing with yearly monetary inputs like seed or fertilizer. A stream of cash inflows and outflows is connected to every machine action. In this study, the economic evaluation of baler technology for managing paddy straw was conducted from the perspective of the machine owner. At the field level, two systems of using baler technology were generally used: System I and System II. In system I, the machine owner is taking rent in Indian Rupees (₹) from farmers for operating stubble shaver, rake and baler machine on farmer's field for making bales and cleaning the field by collecting them. After collection machine owner sold the bales to the biomass power generation plant (situated under a radius of 35 kilometers) @ ₹ 1300 per ton. On the other hand, in system II, the machine owner operates only the rake and baler machine at the farmer's field, as the farmers operate the stubble shaver (**Figure 2**). The farmer retains the bales made by the baler machine and gives the rental charges @ ₹ 6350 per ha to the machine owner. System I involve the twine and transportation cost (**Figure 3**) @ ₹ 185 per kg and ₹ 450 per tonne, but system II does not involve the transportation cost as the farmers retain the bales. The actual field capacity of the machines was calculated by recording the actual area covered by the machine in the total actual time taken. Fuel consumption was determined by measuring the amount of fuel that was added to the tank both before and after use (Malik *et al.,* 2017).

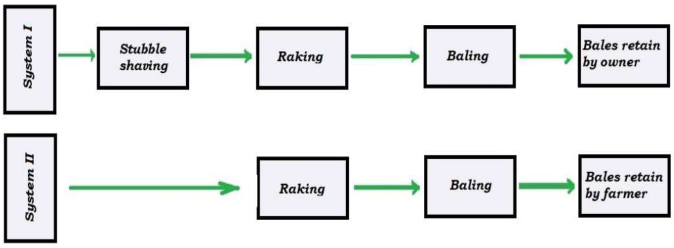

Figure 2: Flow diagram of use of baler technology in system I and II

Figure 3: View of transportation of bales formed by baler

There are many different definitions, each with its pros and cons, of the various economic criteria that must be considered. Therefore, it becomes essential to adopt precise definitions for the various economic terms used and clearly lay down the conventions of calculating them. The three assumptions used for the present study are:

1. The tractor is already available with the owner.
2. Throughout the project's duration, all of the equipment are paid for with cash and the operating technology is unchanging.
3. All inputs, outputs prices and conversion rates remain the same throughout the study period.

The complete cost of baler technology at the field level is comprised (Rahman *et al*., 2013) of fixed and variable costs. Fixed costs include depreciation, interest on investment, shelter expenses, taxes, insurance and housing costs, among others. Variable costs encompass fuel expenses, lubricants, operator salaries, labour costs, repairs and maintenance.

Fixed Cost (FC)

A *fixed cost* pertains to a resource with a definite quantity that does not vary when the output level does. Since the average yearly cost of the equipment is frequently the only factor to be considered, the straight-line technique, which is the easiest to calculate depreciation, is commonly employed in budgeting (Barnard and Nix, 1980). Consequently, straight-line depreciation is presumed in the computation of fixed cost and the yearly depreciation was determined using the following formula:

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

where,

D : depreciation, ₹ per yr

P : machine purchase price, ₹

S : machine salvage value, ₹

L : machine life in years, yr.

The fixed cost estimate considers the interest in purchasing a baler technology. Since the investment funds cannot be utilized for other interest-paying businesses, a charge is applied even if they are not borrowed. There is a 12% interest rate. The investment interest was computed using the following formula:

where, i : interest rate, decimal.

Variable cost (VC)

Variable costs are those that vary with changes in production level. Hourly labour, gasoline, oil, repair and maintenance expenses and hours needed for each field activity affect variable costs. The labour rate of ₹/h was used to compute the cost of labour for the operator. The consumption rate was used to determine the expenses of gasoline and oil, which were subsequently multiplied by the prices for each.

Operating cost (OC)

There were two categories of annual operating costs for the machinery employed in this study: fixed and variable. Following converting the computed fixed and variable costs into ₹/ha (Rs/h), the total of the fixed and variable costs was supplied OC in ₹/ha (₹/h). Following is the computation of the OC:

OC, ₹/ha = Fixed cost +Variable cost

Break Even Point (BEP)

Many farmers want assistance selecting or purchasing all the equipment needed for farming. This is frequently due to a need for more resources, labour, tiny land holdings, or other factors. These farmers get the necessary machinery services for their farms by employing bespoke services. Compare the fixed and variable costs of owning and running the machinery to the overall expenses of bespoke service to determine if owning or engaging a client operator is more cost-effective. The break-even point (Gutierrez and Dalsted, 2020) is found faster and more accurately with the following formula:

where,

F: Annual fixed costs

V: Variable costs per unit of operation

R: Custom hiring charge/rent per unit

Payback period

The time frame whereby revenues can offset the costs of the investment is referred to as the payback. Stated differently, it is the amount of time needed for the cash flow generated by an investment to match the initial outlay made. The desirability of an investment is directly related to its payback period. Shorter paybacks mean more attractive investments (Mohammad *et al.*, 2019). This can be computed by applying the following formula:

Benefit-cost ratio (BCR)

The present value of the benefit stream divided by the present value of the expense stream is known as the benefit-cost ratio. In theory, the benefit-cost analysis approach is straightforward. Equation following provides it and it follows the methodical process of choosing amongst economic investment options (Guttinger, 1994):

A BCR greater than one indicates a profitable investment. To avoid duplicate accounting, depreciation and investment interest are not included in the costs. Including the investment cost accounts for depreciation, while the discount factor accounts for the interest of investment.

Utility index

It is an exact representation of the hours of labour machine interaction. The operation cost and the non-operating hours reduce as the utility index rises. This ultimately leads to a net gain in the overall electricity that may be used for agricultural tasks. One may compute the utility index (K) as follows:

Results and Discussions

For an entrepreneur, custom operator, or progressive farmer, the business of collecting paddy straw using baler technology and providing custom hiring services is a cyclical venture that takes place during the combine harvesting of rice crops. The total cost of baler technology operations at the farm level comprises variable and fixed costs. Depreciation of the machine was calculated using the straight-line method and taken as a fixed cost. The findings indicated that investing in baler technology proved to be profitable for entrepreneurs. The subsequent section outlines the significant cost and return elements associated with operating a baler technology business in custom hire entrepreneurship:

Economic analysis

The economic analysis of using the baler technology and various assumption made during the analysis for both systems is given in **Table 1**. The financial analysis was calculated from the perspective of the machine owner, who may be a progressive farmer or a custom hired operator. Based on field data, the baler technology total operating cost for the system I and II were estimated as ₹ 4285.74 per hour and ₹ 2374.34 per hour. The actual field capacity of the baler, rake and stubble shaver machine was 0.53, 0.79 and 0.51 ha per hour having fuel consumption of 6.6, 4.8 and 4.25 per hour respectively. Fixed and variable cost for the machine operation were calculated as ₹ 629.2 and 3656.54 per hour for system I and 609.4 and 1764.94 per hour for system II based on the average field data collected through personal interviews of custom-hire service providers. The amount of twine used was 6.35 kg per ha costing ₹ 622.62 per hour. In case of system I, the transportation cost including loading the bales on the trolley and transport to the buying point (biomass power plant) was 1514.48 ₹ per hour. In operating the baler machine for system I, the total per hour operating cost was estimated as ₹ 3313.39, which includes a total fixed cost of ₹ 484, total variable cost of ₹ 866.54 and twine cost of ₹ 622.62 and transportation cost of ₹ 1514.48 respectively. This showed that the bale transportation cost (from the collection point to the selling point) was the major contributor (45.70%) in the baling system I, followed by the variable, twine and fixed costs. In system II, however, the bale transportation cost was not included as the farmers kept the bales. The total per-hour operating cost for operating the baler machine in system II was ₹ 1798.91, which includes the maximum contribution (38.48%) from variable cost followed by twine and fixed cost. The total per hour operating cost was computed as ₹ 575.43 for both the system and the major contributor of cost (78.21%) in operating the rake machine was variable cost followed by fixed cost. The total per-hour operating cost of the stubble shaver machine (for system I only) was ₹ 396.93 and the significant contribution (95.01%) was from variable cost followed by the fixed cost. The various itemized cost per hour for both systems were analysed and presented (**Figures 4 and 5**).

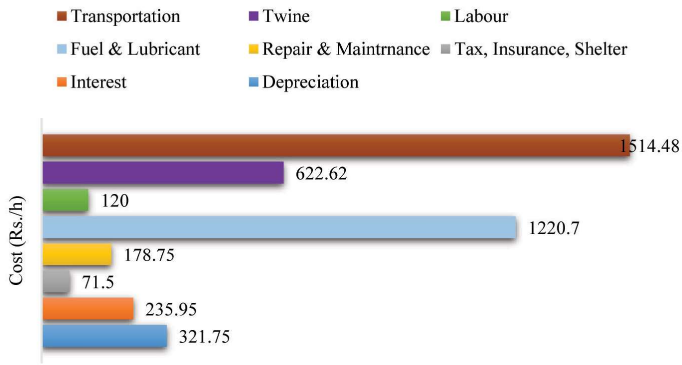

Figure. 4: Itemized cost per hour of operation for system I

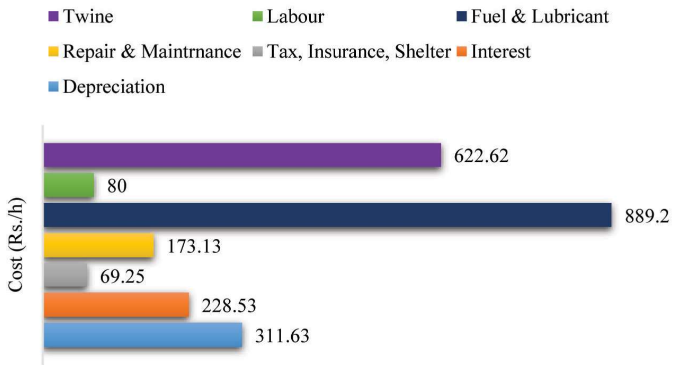

Figure 5: Itemized cost per hour of operation for system II

Table 1 Economic analysis of system I and II

System I: Operator retaining the bales and selling to power plants					System II: Farmer retaining the bales	
Particulars	**Assumption**	**Baler**	**Rake**	**Stubble shaver**	**Baler**	**Rake**
Purchase price, ₹	P	1100000	285000	450000	1100000	285000
Salvage (S), ₹	10% of P	110000	28500	4500	110000	28500
Life, yr	-	10	10	10	10	10
Economic life, h	-	400	400	400	400	400
Depreciation, ₹/yr	-	99000	25650	4050	99000	25650
Interest cost, ₹/yr	Rate of interest, 12%	72600	18810	2970	72600	18810
Tax, insurance, shelter, ₹/yr	2% of P	22000	5700	900	22000	5700
Fixed Cost, ₹/yr (₹/h)	-	193600	50160	7920	193600	50160
Total fixed cost (FC), ₹/yr (₹/h)	-		251680 (629.2)		243760 (609.4)	
Repair & maintenance, ₹/h	5% of P/Avg/yr	137.5	35.63	5.63	137.5	35.63
Fuel cost, ₹/h	@ ₹ 87/litre	574.2	399.18	369.75	574.2	399.18
Lubrication cost, ₹/h	20% of Fuel Cost	114.84	79.836	73.95	114.84	79.836
Labour Cost, ₹/h	-	40	40	40	40	40
Variable cost (VC), ₹/h	-	866.54	554.646	489.33	866.54	554.646
Twine cost, ₹/h (Twine used 6.35 kg/ha)	₹ 185/kg	622.62	-	-	622.62	-
Transportation cost, ₹/h	₹ 4.5/ton	1514.48	-	-	-	-
Operating cost (OC), (₹/h)		3313.39	575.43	396.93	1798.91	575.43
Total operating cost, ₹/h	-		4285.74		2374.34	

Economic worth assessment

The details of all economic parameters for assessing the economic worth of implementing baler technology were presented (**Table 2**). The rental charges for using baler technology by a customer operator is ₹ 1346.2 per hour for the system I and 3365.5 per hour for system II. The net benefit comes out to be ₹ 998.09 and 991.16 per hour (**Table 2**) for the system I and II. Considering 150 hours of annual use of baler technology according to the custom operators the net annual benefit or revenue was observed to be ₹ 399237 and 396463 for the system I and II.

After a detailed economic analysis of systems I and II, it has been observed that the net benefits per ha were ₹ 1883.19 and 1870.11, which showed that the net benefit was almost at par for both systems. Therefore, both systems followed by the machine owner or baling service provider gave at-par financial benefits. Therefore, if a new entrepreneur or progressive farmer wants to start a new venture of collecting and selling paddy straw, they can choose systems I and II. Considering the capital cost involved in the purchase of baler technology for both the systems and the assumption made for economic analysis in this study, the break-even point comes out to be 81.97 ha or 154.66 ha per year and 80.72 ha 152.23 hours per year for the system I and System II (**Figures 6 and 7**). In contrast, the actual use of baler technology is approximately 400 hours per year by the custom operator. Considering the actual annual use of baler technology, the custom operator or progressive farmer shall be able to recover his cost in 3.58 and 3.49 years (payback period). Mangaraj and Kulkarni (2011) have reported a payback period of 5 years while studying the techno-economic perspectives of baler machines. Both systems are profitable from the viewpoint of custom operators. The payback period of both the systems is less than the life (10 years) of the baler technology machinery and also, the benefit-cost ratio for both systems I and II are found to be 1.23 and 1.42, which is greater (>) than unity. Pal *et al.*, (2019) reported a benefit-cost ratio 1.39 for collecting paddy straw with a baler machine after harvesting paddy crops with a combine harvester. So implementing baler technology for managing paddy straw by its collection, is an acceptable venture from the business point of view. The utility indexes obtained were 2.58 and 3.64 for system I and II which are greater than unity. This indicates efficient utilization of baler technology.

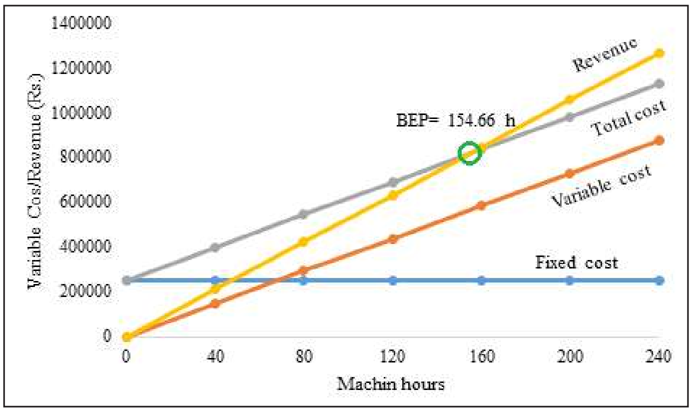

Figure 6: Economic use of baler technology for system I

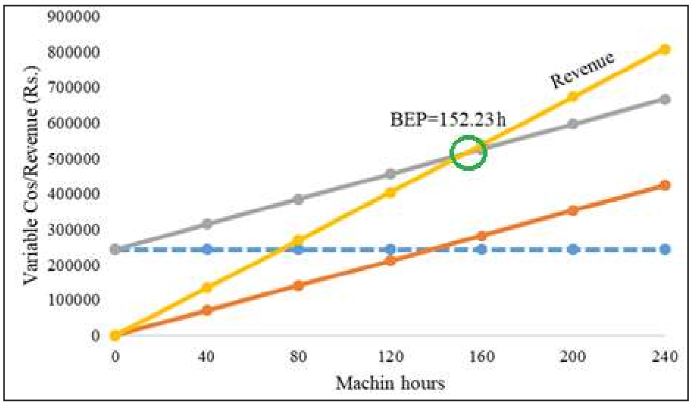

Figure 7: Economic use of baler technology for system II

Table 2: Baler technology economic worth assessment

System I: Operator retaining the bales and selling to power plants			System II: Farmer retaining the bales	
Items	**Value**	**Remarks**	**Value**	**Remarks**
Actual field capacity, ha/h	0.53	Field capacity of straw baler after operation of rake	0.53	Field capacity of straw baler after operation of rake
Rental revenue, ₹/ha (₹/h)	2540 (1346.2)	Rent for cleaning the field by making and collecting bales	6350 (3365.5)	Rent of making bales only
Straw collected, ton/ha	6.32	Average amount of straw collected from one ha	-	-
Revenue form straw sale, ₹/ha (₹/h)	8255 (4375.15)	Sold at the rate of ₹ 130 per quintal	-	-
Revenue after moisture cut, ₹/ha (₹/h)	7429.5 (3937.64)	10% moisture cut generally applied by buyer	-	-
Total revenue, ₹/ha (₹/h)	9969.5 (5283.84)	-	6350 (3365.5)	-
Net Benefit, ₹/ha (₹/h)	1883.19 (998.09)	-	1870.11 (991.16)	-
Annual Benefit (₹)	399237	-	396463	-
Actual Payback period (yr)	3.58	Less than economic life of machine (<6 yr)	3.49	Less than life of machine (<10 yr)
Break-even point ha/yr (h/yr))	81.97 (154.66)	More than the actual covered area	80.72 (152.23)	Less than the actual covered area
Benefit-cost ratio (BCR)	1.23	Greater than unity (>1)	1.42	Greater than unity (>1)
Utility index	2.58	Greater than unity (>1)	3.64	Greater than unity (>1)

It was observed that, although both the system of implementing baler technology is acceptable, system II is a little bit more beneficial as it is having benefit-to-cost ratio and less payback period than system I. This is due to the absence of cost involved in the operation of the stubble shaver machine and the absence of capital cost required to purchase the stubble shaver machine. In system II, farmers retain the bales, which they can sell to some other buyer at a higher price to get additional benefits or can use them for another purpose, such as the production of bioenergy and use in the packaging as a mushroom growth medium and paper industry, as natural manure (worm-compost), etc. Implementing baler technology also generates employment for the rural youth by engaging the youth in loading and unloading, transporting the bales, etc.

Limitation in Implementing Baler Technology

This study's budgeting process only permits the consideration of variables that can be measured and for which accurate estimates are available. Therefore, when employing the baler technology, the potential restrictions of the situational elements are not considered. The profit or revenue generated from using baler technology largely depends upon the sale price of the straw. If the sale price of paddy straw goes down or machine operators do not get the appropriate price, then the implementation of baler technology is considerably affected. There are also hidden costs, such as twine, labour and bales transportation costs, including using baler technology. The significant variation in these hidden costs may affect the implementation of the baler technology. The number of machinery and their high initial cost can also be hindrances in choosing the baler technology. The sole thing contributing to rising expenses per unit is the tardiness of field operations. On the other hand, management is responsible for operations scheduling. Only until a predetermined pattern of operations - including the dates and orders of each field operation - is defined can the budgeting approach be applied. Any disruption to this pattern results in untimeliness losses. But managing each circumstance to maximize gains or prevent losses is the manager's job. Depending on the situation, an observant owner or management may alter this operation pattern. The output from the baler technology also depends upon the skill of the machine operator. While operating the straw collection machinery, an unskilled operator can cause damage to the machinery, thereby halting the collection process and ultimately resulting in revenue loss. Biomass power plant operators apply 10% of the moisture cut if the bales come to them, which is moister than the desired level, which further reduces the income from selling the straw bales. So, keeping the moisture level of paddy straw within the limit while selling to the buyer is another challenge to the machine operator/owner to avoid an unnecessary reduction in revenue.

Therefore, it is worth mentioning that before implementing baler technology, a machine owner/progressive farmer/custom operator must ensure where they will sell the bales or their end-use. This exercise must be done before adopting the baler technology. Further, the help of government aid, such as providing subsidies on the machinery involved in the baler technology or developing more power plants or other practical industries which can utilize the paddy straw, can enhance the decision to use baler technology by the progressive farmer or service provider. Machine custom hiring centres or societies can be developed to enhance the availability of machinery to the individual or end user. The grouping of farmers can be done so that they can buy the costly baler technology machinery collectively and can implement this technology at the village or block level to earn and avoid straw burning issues. This will enhance the economic condition of farmers/entrepreneurs/service providers along with the avoidance of the infield burning of paddy straw problems, which will safeguard the overall ecosystem.

Conclusion

According to the study, implementing baler technology for paddy straws management by straws collection is profitable. The additional benefit is that paddy straw burning (on-farm) can be avoided, which is beneficial and much needed for the environment, agriculture and living beings. The economic worth assessment showed that the total operating cost and net benefit for systems I and II were estimated as ₹ 4285.74, 2374.34, 998.09 and 991.16 per hour for systems I and II. The benefit-cost ratio of systems I and II of baler technology was found to be 1.23 and 1.42 (greater than unity), which makes it a profitable and acceptable venture for an entrepreneur. The break-even usage of the baler technology was appraised at 154.66 and 152.23 hours per year of machine operation for systems I and II. The utility indexes obtained in system I and II were 2.58 and 3.64 which are more than unity.

The economic indicators determined in the present study indicates the efficient and beneficial baler technology venture. The owners of baler technology or progressive farmers/service providers can embrace this profitable venture and get monetary benefits while contributing to the reduction of paddy straw burning and the associated environmental pollution.

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