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Techno-economic feasibility of a grain recovery machine for manually harvested wheat fields

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Abstract

Wheat is a major cereal crop and an essential component of food security in India. Although mechanized harvesting is expanding in large farms, manual harvesting remains common among small and marginal farmers, especially in fragmented holdings. A practical problem after manual harvesting is the presence of loose grains and residual wheat spikes on the field surface. These residues are often recovered manually through bending, squatting, and repetitive hand collection, which makes the operation slow, costly, labour intensive, and ergonomically unsafe. The present paper develops a techno-economic feasibility analysis of a tractor-operated grain recovery machine designed for manually harvested wheat fields. The uploaded presentation describes a machine based on pneumatic suction, consisting of a suction unit, blower assembly, collection chamber, frame, power transmission system, supporting wheels, and tractor PTO power source. The economic analysis indicates an initial machine cost of Rs 50000 a useful life of 10 years, annual operating time of 240 h, total fixed cost of Rs 7,750 /year, total variable cost of Rs 89500 /year, and total operational cost of Rs 97250 /year. With a collection capacity of 12 kg/h, the annual collection output is 28.8 q, giving a machine collection cost of Rs 3376.73/q and Rs 3517.43/day. Compared with manual collection cost of Rs 2000 /day, the machine shows a financial loss of Rs 2083.33/q under the present operating assumptions. However, the same machine offers important non-monetary benefits by reducing bending posture, fatigue, labour dependence, psychological stress, and direct physical involvement in grain recovery. The paper concludes that the present prototype is ergonomically promising but economically infeasible unless collection capacity increases, fuel cost decreases, annual utilization improves, or the machine is redesigned for lower operating cost.

Keywords: Grain recovery machine, wheat, manually harvested field, cost analysis, ergonomic benefit, break-even, agricultural mechanization

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world and plays a significant role in ensuring food security and supporting rural livelihoods. In India, despite the increasing use of combine harvesters, manual harvesting with sickles is still widely practiced on small and fragmented farms. During harvesting, bundling, transportation, and field handling operations, a considerable quantity of wheat spikes and loose grains remains scattered on the field surface, resulting in avoidable post-harvest losses. Traditionally, these residual spikes are collected manually, a process that is labour-intensive, time-consuming, and physically demanding. (FAO, 2024) [5].

Manual grain collection requires continuous bending, squatting, and repetitive hand movements, which increase physical fatigue and musculoskeletal discomfort among farm workers. In addition, the shortage of agricultural labour and increasing wage rates during the harvesting season have made manual collection less economical. These challenges have created a need for an efficient and affordable mechanized solution to recover wheat spikes while reducing labour requirements and improving working conditions. (Anusha and Mehta 2021) [1]. To address this problem, a tractor-operated grain recovery machine was designed and developed for collecting wheat spikes and loose grains from manually harvested fields.

The machine operates on the principle of pneumatic suction, in which a blower powered by the tractor power take-off (PTO) generates airflow to lift and convey wheat spikes into a collection chamber. Besides reducing grain losses, the machine minimizes manual drudgery and improves operator comfort during field operations (Mishra *et al.*, 2017) ^[9].

However, the successful adoption of any agricultural machine depends not only on its technical performance but also on its economic viability. Therefore, a techno-economic evaluation is essential to determine whether the operational benefits justify the investment and operating costs. The present study evaluates the fabrication cost, fixed and variable costs, operational cost, and collection cost of the developed grain recovery machine and compares its economic performance with conventional manual collection. In addition, the study discusses the ergonomic advantages of the machine and suggests measures to improve its economic feasibility under practical farming conditions. (Singh and Mehta, 2015)^[14]

Description of the Grain Recovery Machine

The developed grain recovery machine is a tractor-operated implement designed to recover wheat spikes and loose grains remaining in manually harvested fields. The machine operates on the principle of pneumatic suction, whereby a centrifugal blower generates sufficient airflow to lift residual wheat spikes and grains from the field surface and convey them into a collection chamber. The machine is powered through the tractor power take-off (PTO), enabling continuous field operation under different working conditions.

The machine consists of six major assemblies: the supporting frame, blower assembly, suction duct, collection chamber, power transmission system, and ground-engaging wheels. The supporting frame provides structural stability and supports all functional components during operation. The blower assembly generates the required suction pressure for lifting wheat spikes and loose grains, while the suction duct directs the material into the collection chamber, where the recovered grains and spikes are separated from the airflow and stored for subsequent handling. Power from the tractor PTO is transmitted to the blower through a pulley and V-belt transmission system, ensuring reliable and efficient operation under varying field conditions.

The machine requires only one tractor operator for its operation, thereby considerably reducing the labour required for grain collection. During operation, the tractor moves the machine over the manually harvested field, allowing the suction duct to collect scattered wheat spikes and grains without the need for continuous manual bending or hand picking. The developed machine was fabricated using locally available materials, including mild steel sections, mild steel sheets, shafts, pillow

block bearings, wheels, belts, and standard fasteners. The total fabrication cost of the developed grain recovery machine was Rs. 50000.

Materials and Methods

The economic feasibility of the developed tractor-operated grain recovery machine was evaluated using the performance data obtained under optimized operating conditions. Prior to the economic analysis, the machine was tested under different combinations of forward speed and suction pressure to identify the optimum operating parameters for maximum grain recovery efficiency. The performance evaluation considered important response parameters, including grain recovery efficiency (%), output capacity (kg/h), field capacity (ha/h), and grain losses (%). Based on the optimization results, the machine exhibited an average collection capacity of 12 kg/h which was considered for the techno-economic analysis.

The economic evaluation was carried out following the standard procedure recommended in BIS: 9164–1979^[3] for estimating the operating cost of agricultural machinery. The total fabrication cost of the developed grain recovery machine was Rs. 50000 with an expected service life of 10 years (7200 operating hours). Fixed costs included depreciation, interest on investment, and housing, insurance, and taxes, whereas variable costs comprised repair and maintenance, tractor operator wages, and fuel consumption. The machine was assumed to operate for 30 days per year, with an average of 8 operating hours per day, resulting in 240 annual working hours.

To compare the mechanized system with the conventional practice, the cost of manual grain collection was estimated using prevailing agricultural labour wages. The machine collection cost (Rs./q) was determined from the annual operational cost and annual machine productivity. The economic feasibility of the developed machine was assessed through estimation of annual operating cost and collection cost and compared with manual grain collection to evaluate its practical suitability under manually harvested wheat field conditions.

Fixed cost per annum

The fixed annual cost is a summation of the interest cost, depreciation cost, insurance cost and housing tax per year of the machine. The annual charges of interest were calculated as 10% average investment on the machine. The useful life of the agriculture machinery was described to be 10 years, on this behalf, the useful life of the machine was taken 10 years (Mishra *et al.*, 2017) ^[9] The salvage value of the machine was taken 10% of the purchase price (.The formula for interest rate, depreciation cost, insurance cost and house tax is given in Eq. 1, 2, 3 and 4, respectively.

$$A. \text{ Interest rate} = \frac{\text{Machine cost} + \text{Salvage value}}{2} \times 0.10 \quad (1)$$

$$B. \text{ Depreciation cost} = \frac{\text{Machine cost} - \text{Salvage value}}{\text{Useful life of machine (year)}} \quad (2)$$

$$C. \text{ Insurance} = 2\% \times \text{cost of machine} \quad (3)$$

$$D. \text{ House tax (H)} = 1\% \times \text{cost of machine} \quad (4)$$

Variable Cost per Annum

The annual variable cost of the developed grain recovery machine comprised repair and maintenance cost, tractor operator

wages, and fuel cost incurred during field operation. Repair and maintenance cost was considered as 5% of the initial machine cost, following the standard farm machinery costing procedure

recommended by (Singh and Mehta 2015)^[14] Since the developed machine is powered through the tractor power take-off (PTO), fuel consumption of the tractor was considered instead of electricity charges. The operator cost was estimated based on the prevailing daily wage rate and the annual working

days of the machine. The formula for calculation of operator cost of the workers and total variable cost is given in Eq. 5 and 6, respectively. Repair and maintenance assumptions are also supported by Calcante *et al.* (2013)^[4]

The operator cost was calculated using the following equation:

$$A. \text{ Operator cost} = \text{Daily charge} \times \text{Working hours of the machine in a year} \quad (5)$$

$$B. \text{ Total variable cost per annum} = \text{Repair and maintenance cost} + \text{Operator cost} + \text{Fuel cost} \quad (6)$$

Total operational cost of machine per annum

The total operational cost of the machine per annum was the summation of the fixed cost and variable cost of the machine. (Eq. 7).

$$\text{Total operational cost of machine per annum} = \text{Total fixed cost} + \text{Total variable cost} \dots (7)$$

Machine Productivity per Annum

The annual productivity of the developed grain recovery machine was estimated from its average collection capacity and the total annual operating hours. Machine productivity represents the total quantity of wheat spikes and loose grains that can be recovered under normal operating conditions in one year. The actual collection capacity obtained during field evaluation was used for estimating the annual productivity of the machine.

The annual machine productivity was calculated using the following equation:

$$\text{Machine productivity per annum} = \text{Total working hour/year} \times \text{actual capacity} \dots 8$$

Profit Analysis

The economic performance of the developed grain recovery machine was evaluated by comparing the cost of mechanized grain collection with the conventional manual collection method. The comparison provides an estimate of the economic advantage or disadvantage of adopting the developed machine

under manually harvested wheat field conditions. (Mishra *et al.*, 2017)^[9]

The annual profit (or saving) obtained by using the machine was calculated as the difference between the cost of manual grain collection and the machine collection cost for the same quantity of recovered grain. The Profit (per quintal) of the collection of machine was calculated using the formula given in Eq. 9.

$$\text{Profit} = \text{Manually collection Cost/q} - \text{Machine collation cost} / \text{q} \dots 9$$

3. Results and Discussion

3.1 Economic Aspect: The economic performance of the developed grain recovery machine was evaluated by comparing its operating cost with the conventional manual grain collection method. The machine achieved an average collection capacity of 12 kg/h (96 kg/day) under the optimized operating conditions. The total annual operational cost of the machine was estimated at Rs.97250, resulting in a collection cost of Rs.3376.73 per quintal. For comparison, manual collection of an equivalent quantity of wheat spikes was assumed to require four labourers, each paid Rs.500 per day, resulting in a manual collection cost of Rs.2083.33 per quintal. Under these conditions, the machine incurred an additional collection cost of Rs.1293.40 per quintal compared with manual collection. Although the machine was not economically superior under the present utilization level, it offered important advantages by reducing labour dependency, minimizing operator fatigue, and improving the timeliness and efficiency of grain collection.

Table 1: Economic parameters of the machine and manual operation

Description	Unit	Value	Cost
Cost of Machine	Rs.	50000	
Life in years	years	10	
Life in hours	h	7200	
Depreciation	Rs.	4500	4500
Total interest	Rs.	2750	2750
Housing, Ins. Tax	Rs	500	500
Total Fixed Cost	Rs		7750
Maintenance/year	Rs.	2500	2500
Total working days per year	days	30	
Total hours	h	240	
Labour Charges	Rs./day	500	15000
Fuel per hour	Rs./h	300	
Fuel per year	Rs./year	72000	72000
Total Variable Cost	Rs.		89500
Total operational Cost Per Year	Rs.		97250
Collection cost by machine			
Machine Collection kg per h	Kg/h	12	
Machine Collection kg per day	Kg/day	96	
Machine Collection q per year	q/year	28.8	
Machine collection Cost per q	Rs./q	3376.73	3376.73
Machine collection Cost per day	Rs./day	3517.43	3517.43
Compare with manually collection Cost at same capacity			
Labour charge	Rs.	4	2000
Manually Collection cost per q	Rs./q		2083.33
Profit		-1293.39	

Under the assumed operating conditions of 30 working days per year and an annual utilization of 240 h, the operating cost of the developed grain recovery machine was estimated at Rs.97250 per year presented in Table 1. With an average collection capacity of 12 kg/h the machine collected 28.8 q /year, resulting in a collection cost of Rs.3376.74 /quintal. Manual collection at the same daily capacity required four labourers and incurred a collection cost of Rs.2083.33/ quintal shows as Fig. 1. Thus, under the present assumptions, the developed machine was

Rs.1293.41/ quintal more expensive than manual collection. However, the machine offers advantages such as reduced drudgery, consistent performance, timely residue recovery, and lower dependence on seasonal labour availability. With higher annual utilization or improved field capacity, the collection cost per quintal can be reduced substantially, thereby improving the economic feasibility of the machine Similar trends have been reported by Verma *et al.* (2024)^[15]

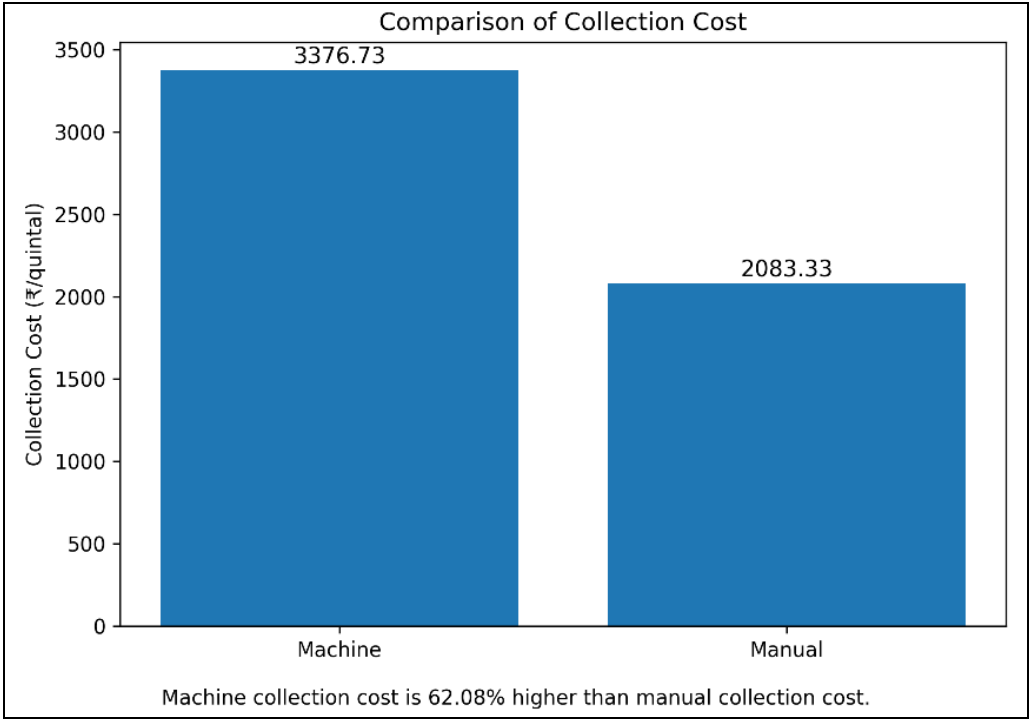


Fig 1: Comparison between machine and manually collection cost

Table 2: Ergonomic parameters of the machine

S. No.	Economic Benefit	Ergonomic Benefit
1	Reduced grain losses Recovering grains left after harvesting increases total grain yield	Reduced bending posture The operator does not need to continuously bend for collecting grains, reducing physical strain.
2	Reduced dependency on manual labour Labour requirement for grain collection is reduced, particularly during labour shortage periods.	Reduced fatigue Mechanized operation decreases physical exertion and operator fatigue.
3		Improved working posture Operator works in a more comfortable Seating on tractor-mounted position.
4		Improved working posture Operator works in a more comfortable Seating on tractor-mounted position.
5		Reduced psychological stress Faster completion of work reduces workload pressure during harvesting season. Faster completion of work reduces workload pressure during harvesting season.
6		Better human-machine interaction Grain recovery machine reduces direct physical involvement in grain collection

Conclusions

The economic analysis indicated that the developed grain recovery machine had an annual operating cost of Rs.97250. At an average collection capacity of 12 kg/h, the machine recovered approximately 28.8 q /year, resulting in a collection cost of Rs.3376.74 per quintal. Under the same collection capacity, manual collection using four labourers cost Rs.2,083.33 per

quintal, which was lower than the machine cost under the present operating conditions. The higher machine cost was primarily attributed to its low annual utilization (240 h year⁻¹) and relatively low field capacity. Nevertheless, the developed machine offers important practical advantages, including reduced labour requirement, lower operator drudgery, timely collection of wheat grains and spikes, and reduced dependence

on seasonal labour availability. These findings are consistent with previous techno-economic evaluations of farm machinery (Mishra *et al.*, 2017)^[9]

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