Original Research Article

Economic Evaluation of Precise Intelligent Cauliflower Harvester: A Comparative Study with Manual Harvesting

ABSTRACT

Aim: The traditional harvesting of cauliflower has been done by hand using labor-intensive, expensive, and time-consuming techniques that frequently lead to significant yield losses because immature curds are harvested without selection. A rising number of people are interested in creating selective cauliflower harvesters that can precisely detect and gather healthy, mature heads while reducing damage, waste, and labor-intensive operations in response to these difficulties. The purpose of this research article is to present a thorough analysis of the ownership and operating costs related to this kind of selective harvesting technology.

Methodology: Through accurate cost insights, farmers can make well-informed decisions on the purchase of new machinery, the maintenance, and upkeep of current equipment, or the investigation of alternative approaches to improve farm productivity and financial results. The economic assessment was conducted through the computation of operating costs utilizing the straight-line method, coupled with breakeven point analysis and determination of the payback period.

Results: The developed selective harvester's ownership and running costs are calculated to be 58.41 and 75.5 rupees per hour, respectively. The selective harvester has several advantages over typical manual harvesting techniques, as demonstrated by a comparative analysis. In particular, the selective harvester shows a remarkable 24.6% cost reduction in addition to saving an astounding 60.6% of the necessary time.

Conclusion: These results highlight the efficiency and financial gains that come with using selective cauliflower harvesting technologies. This analysis is further utilized by farmers for decision-making.

Keywords: Cost economics, Selective cauliflower harvester, Ownership cost, Operating cost, Break-even point, Payback period

1. INTRODUCTION

Within the agricultural landscape, the pivotal role of machinery and equipment in facilitating efficient farm operations cannot be overstated. However, the acquisition of these indispensable tools is accompanied by a substantial financial investment. In recent times, there has been a notable escalation in the costs associated with farm machinery and equipment. Contributing factors to this upward trend include the introduction of larger machines capable of handling increased workloads, the integration of advanced technology in newer models, elevated prices for replacement parts, and heightened energy costs required for powering these machines. Furthermore, the environmental impact of fuel-operated machines, such as combine harvesters, sprayers, and dryers emitting harmful gases like CO and CO_2, has drawn attention to the urgent need for sustainable and eco-friendly agricultural practices (1,2). Recognizing the interconnectedness of agricultural practices and climate change, it becomes imperative to explore avenues for efficient and sustainable technology use to mitigate environmental impacts.

The global surge in the Electric Vehicles (EVs) market over the past decade, acknowledged for its contribution to combatting climate change and enhancing ecological sustainability (3), serves as a noteworthy example. Despite the escalating costs associated with farm machinery, astute farmers and researchers have demonstrated that effective management and control of machinery expenses are achievable through the incorporation of electronics and instrumentation (4). Implementing smart practices and making informed decisions in various farm operations enable them to maintain costs per acre within manageable limits (5). This ability to exert control over machinery costs emerges as a crucial facet in ensuring the profitability of a farm.

In the context of cauliflower production, the period from 2012 to 2022 witnessed a remarkable growth of 20.9% in cauliflower production and a corresponding increase of 20.7% in the overall cauliflower cultivation area in India (6). Mechanized agriculture, involving the utilization of machinery in farming activities, has played a pivotal role in bolstering the productivity of farm workers. The adoption of mechanized power in agriculture alleviates the physical strain associated with traditional manual practices, accelerates agricultural processes, reduces expenses, and ultimately enhances overall productivity. The prevalence of manual harvesting operations, involving the use of sickles, is common in many developing nations (7). However, this method is time-consuming and demands a significant amount of labor. The transition to mechanized harvesting has been shown to address these challenges and yield substantial improvements in the agricultural sector (8,9). Studies have indicated that agricultural mechanization plays a crucial role in the high-quality agricultural development of agriculture, considering that 50% of overall production costs are associated with harvesting(10,11). Mechanical sowing and field management contribute to uniform crop distributions and growth promotion (12), while the use of standardized agricultural machinery reduces losses and enhances product quality (13). The intricacies of harvester design are influenced by factors such as plant structure, crop use, and agronomic characteristics (14–16).

However, the challenge for farmers lies in determining the opportune moments for investing in new machinery or trading in older equipment. This decision-making process requires a comprehensive understanding of the complete spectrum of costs involved in owning and operating farm machinery (17). It encompasses not only the initial purchase price but also the ongoing expenses related to maintenance, repairs, fuel, and other operational facets. By conducting meticulous assessments of these ownership and operational costs, farmers can glean valuable insights that empower them to make informed choices. These choices may involve acquiring new machinery, optimizing existing equipment, or exploring alternative approaches to enhance their farm's productivity and financial performance.

2. METHODOLOGY

The comprehensive cost analysis of the developed precise intelligent cauliflower harvester is derived through meticulous consideration of the bill of materials and the cost of fabrication, where the latter is established as 25% of the total cost. The resulting total cost is quantified at 49500 Rs. (C). The evaluation of the operational cost of the selective cauliflower harvester is grounded in several assumptions for robust financial modeling.The assumptions guiding the determination of the cost of operation for the selective cauliflower harvester are as follows:

- Useful life hours of the machine per year (H): Set at 200 hours.
- Useful life years of the machine (L): Established as 6 years.
- Salvage value (S): Calculated at 10 percent of the initial cost.
- Repair and maintenance cost per year: Determined as 10% of the initial cost.
- Interest rate (i): Set at 12 percent of the initial cost.

• Shelter and insurance: Considered as 2 percent of the initial cost.
• Price of electricity: Priced at 0.75 Rs/h.
• Labour wages: Fixed at 400 Rs/day for an 8-hour workday.
• Depreciation method: Employing the Straight-Line Method.

2.1 Machinery Cost

Within the realm of farm equipment, two predominant cost categories prevail: ownership costs and operating costs. Operating costs exhibit variability directly tied to the frequency of equipment usage, while ownership fees remain constant irrespective of machine utilization, as outlined by (18). The accurate determination of these charges remains elusive until the equipment is either sold or reaches the end of its operational life. However, a reasonably close estimation can be attained by formulating assumptions regarding equipment lifespan, annual consumption rates, and associated labor and fuel expenses. This publication incorporates a dedicated worksheet designed to facilitate the calculation of costs pertinent to a specific machine or process.Ownership costs, often termed fixed costs, encompass a spectrum of financial components, including housing, insurance, taxes, depreciation, interest (referred to as opportunity cost), and various ancillary expenses. In contrast, operating costs, denoted as variable costs, encompass wage expenditures for operators, gasoline, and lubrication, as well as costs associated with repairs and maintenance. This dichotomy between ownership and operating costs delineates the financial intricacies associated with farm equipment.

2.1.1 Ownership Cost

Ownership costs, commonly referred to as fixed costs, encompass the recurrent financial commitments associated with asset ownership. This category comprises various expenditures, such as depreciation, interest (termed as opportunity cost), taxes, insurance, and the costs affiliated with housing the respective asset or property. These fixed costs represent a consistent financial outlay for owners, irrespective of the degree of asset utilization or operational activity.

2.1.1.1 Depreciation

Depreciation constitutes a financial consideration linked to the aging, wear, and deterioration of machinery. The actual value of a machine during trade or sale may deviate slightly or align with average values for comparable equipment, contingent upon its mechanical wear. Additionally, the obsolescence of older devices, arising from significant design changes or technological advancements, may result in a sharp decline in their residual value. Typically, a machine's age and the cumulative hours of usage stand as pivotal criteria for estimating its remaining value. The determination of annual depreciation necessitates specifying the machinery's economic lifespan and the salvage value at the conclusion of its commercial utility.The "economic life of a machine" denotes the number of years over which expenditures must be evaluated, often shorter than the machine's service life due to farmers frequently replacing worn-out equipment with new ones. As a general guideline, most farm equipment boasts a lifespan of 10 to 12 years, with tractors typically having a 10-year lifespan. In the case of the selective cauliflower harvester, the harvester's usable life is designated as 6 years. Salvage value represents the estimated monetary value assigned to a machine as its economic life approaches its conclusion. This figure reflects potential future returns through options like a trade-in allowance when transitioning to a new machine, the expected market value if sold outright, or a value of 0 if the machine is retained until complete depreciation renders it no longer functional. The following expression can be used to get the annual depreciation value.

$$\text{Depreciation (D), Rs/h} = \frac{C-S}{L\times H} \ldots(1)$$

Salvage value (S) =10 percent of the initial cost

=0.10 × 49500
=4950 Rs
Where,
D = Depreciation (Rs/h)
C = Initial cost (Rs)

$$D = \frac{49500 - 4950}{6 \times 200}$$

D = 37.12 Rs/h

2.1.1.2 Interest

Farmers have two principal avenues to finance the acquisition of a harvester: securing a loan from a lender or utilizing their personal funds. Opting for a loan entails the lender establishing an interest rate, influenced by factors such as the farmer's creditworthiness and prevailing market conditions. Conversely, if the farmer opts to use personal capital, the interest rate should be determined by the opportunity cost of the capital concerning alternative potential investments within the farm business. In cases where both borrowing and personal capital utilization are employed, a weighted average of the two interest rates should be considered.In our scenario, let us consider employing an average interest rate of 12 percent to fund the intended harvester acquisition. The subsequent formula is employed to calculate the annual interest on an average investment using the prevailing interest rate:

$$\text{Interest (I), Rs/h} = \frac{C+S}{H} \times \frac{i}{2} \quad \ldots (2)$$

$$I = \frac{49500+4950}{200} \times \frac{0.12}{2}$$

I = 16.33 Rs/h

2.1.1.3 Taxes, Housing, and Insurance

In the overall analysis of owning farm machinery, such as a harvester, the importance of sales tax, road tax, insurance, and shelter charges should not be undervalued, even though they may seem insignificant in relation to elements like depreciation and interest. Even if sales tax and road tax appear to be minor, their impact on annual expenditures can be captured by carefully spreading them out throughout the machine's lifetime. Insurance plays a critical role in reducing the risks related to theft, damage, and disasters, guaranteeing the farmer's capacity to replace or repair the machinery as soon as needed. It is also very worthwhile to provide sufficient cover, tools, and maintenance equipment for the machines. By proactively protecting the machinery from weather-induced wear and tear, this strategy reduces the need for regular on-field maintenance. As a result, this increases the machinery's trade-in value and promotes increased reliability during operations. Combining housing, insurance, and tax costs results in an estimate of about 2% of the average machine cost per year. This computation accounts for insurance and housing expenses, which usually amount to 1% of the machinery's original purchase price annually. When considering the ownership of farm machinery holistically, these very small expenses are important but subtle components of the total financial scenario.

$$\text{Taxes, Housing, and Insurance (THI), Rs/h} = \frac{0.02 \times C}{H} \ldots (3)$$

$$= \frac{0.02 \times 49500}{200}$$

= 4.95 Rs/h

Total ownership cost (TOC), Rs/h = D + I + THI … (4)

= 37.12 + 16.33 + 4.95

= 58.41 Rs/h

2.1.2 Operating cost

Variable costs are intricately linked to the volume of usage, manifesting as expenses that solely occur during the operational phases of the machine. Examples of such costs include repairs, fuel and lubricants, servicing, and labor expenditures. These expenditures are contingent upon the machine's active utilization, establishing a direct correlation between variable costs and the extent of machine use.

2.1.2.1 Repair and maintenance costs

Repair costs result from the need for periodic maintenance, the progressive deterioration of components, and the possibility of accident-related damages. They are incurred to guarantee the regular upkeep of farm machinery. The cost of repairs can vary significantly depending on a number of factors, including the farm's location, type of soil, presence of rocks, prevailing weather, and machine usage practices. Differences in machine management procedures and the skill of those who operate them might cause differences in repair costs even between nearby farms.Keeping detailed records of previous repair charges helps with accurate cost estimation. With the use of this historical data, the owner can spot trends in a machine's repair requirements relative to average expectations, pointing out instances of higher or lower repair frequency. These records are also a useful resource for determining the effectiveness of the maintenance schedule and the owner's level of repair expertise. Without these records, calculating repair costs is reduced to a more generalized exercise based on typical experiences, albeit it may still be less accurate in some circumstances. Given that repair and maintenance expenditures are an inherent part of owning machinery, it is customary to set aside 10% of the machine's annual purchase price to pay for these necessary charges.

Repair and maintenance costs(RMC), Rs/h = $\frac{0.10 \times C}{H}$… (5)

$=\frac{4950}{200}$

= 24.75 Rs/h

2.1.2.2 Labour charges

When it comes to planting or harvesting, the wide range of machines requires different amounts of human labour. Therefore, labour costs should be properly taken into account when thoroughly inspecting machines. Labour expenses become a crucial deciding element when weighing ownership against customized hiring. The labour wages are computed using the real compensation in rupees paid daily, in accordance with the rates that are in effect in the research region. More specifically, the operator of the leafy vegetable harvester receives Rs. 400 per day in compensation. In addition, a single worker is hired for eight hours a day at a cost of Rs. 400 to perform harvesting tasks. This thorough method of evaluating labour costs helps to provide a more nuanced view of the financial effects of different machinery utilization scenarios.

Labour cost (LC), Rs/h = $\frac{400}{8}$..(6)

= 50 Rs/h

2.1.2.3 Electricity

India has always kept its electricity prices lower than those of many other developed countries. The amount of electricity used depends on how much power is charged and how long it takes to charge. In turn, charging voltage and charging current result in charging power. In the computation, a standard rate for power consumption per unit is used. The total units needed by various components are recorded in great detail and serve as the foundation for the calculation of the total electricity costs based on these measured quantities. This methodical technique guarantees a thorough evaluation of electricity prices and offers insightful information about the economic factors related to the use of electrical power in different components.

Electricity charge (EC), Rs/h = 0.75…(7)

Total operating cost (OC), Rs/h = RMC + LC + EC …(8)

= 24.75 + 50 + 0.75

= 75.5 Rs/h

The total cost of the developed harvester (TC), Rs/h = TOC + OC … (9)

= 58.41 + 75.5

= 133 Rs/h

2.2 Cost of harvesting per hectare

The field capacity of the developed harvester= 0.03 ha/h

Cost of operation, Rs/ha = $\frac{Total\ \ operating\ \ cost, Rs/h}{Field\ \ capacity\ ,\ \ ha/h}$…(10)

= 133/0.03

=4433 Rs/ha

Overhead charges @25% of total cost (OC), Rs/h =133 ×0.25 …(11)

= 33.25 Rs/h

2.3 Custom Hiring Charges (CHC)

Agricultural machinery custom hiring fees include official, tailored costs related to renting particular farming equipment. These fees are carefully designed to meet the unique needs of farmers who choose to rent equipment for their farming operations. The cost of hiring agricultural machinery depends on a number of factors, such as the kind of machine desired (such as tractors, harvesters, or ploughs), how long the rental will last, whether extra services are needed, and where the equipment will be used. Due to the fact that every rental agreement is different, fees are carefully calculated in order to create a customized and formalized arrangement that is exactly what the farmer wants. This method guarantees that the budgetary factors related to custom hiring represent an extensive and customized framework appropriate for the particular needs of agricultural tasks.

Custom hiring charges (CHC), Rs/h = (TC + OC) ×25% of profit over new cost…(12)

=(133+33.25) ×1.25

= 208 Rs/h

2.4 Breakeven Point

The break-even point of the harvester is the production or operation level at which all operating costs are equal to all money received from its use. This turning point represents a state of balance, in which there is neither profit nor loss and the company manages to pay all of its expenses without making any more money. Within the business domain, the break-even point is a crucial notion that is often utilized to evaluate the financial viability of ventures and investments. In the case of a harvester, the break-even threshold is reached when the total revenue from harvested crops or any other service provided by the harvester exactly balances all of the expenses associated with the ownership, upkeep, and use of the equipment. When assessing the viability and efficacy of harvester-related investments and activities, a sophisticated grasp of the break-even point is essential.

Break-even point (h/year) = $\frac{Annual\ \ fixed\ \ cost\ (\frac{Rs}{year})}{custom\ \ hiring\ \ charges\ (\frac{Rs}{h}) - operating\ \ cost\ (\frac{Rs}{h})}$ …(13)

$= \frac{58.41 \times 200}{208 - 75.5}$

= 88 h/year

2.5 Payback Period

The payback period for a harvester refers to how long it will take for the total cash flows from using the machine to equal the initial outlay of funds. It is, in essence, the time period during which the harvester "repays" the capital that was invested in its acquisition with the income that it produces. One essential financial indicator that is used to evaluate the risk and return of an investment is the payback period. In general, a shorter payback period is considered advantageous since it suggests a quicker return on investment and a lower probability of lengthy recovery periods. When it comes to assessing the financial sustainability and speed of return on investment for harvester-related ventures, this measure is crucial.

Average net annual profit (Rs/year) = (CHC-operating cost) × Annual use …(14)

= (208-133) ×200

= 15000 Rs/year

Payback period, year = $\frac{Intial\ \ cost\ \ of\ \ machine}{Average\ \ net\ \ annual\ \ profit}$ …(15)

= $\frac{49500}{15000}$ = 3.3 year

2.6 Traditional manual harvesting vs Mechanized selective harvesting

Harvesters have been the most common agricultural machinery in India due to labour constraints during the busiest harvesting season. Harvesting cauliflower by hand using sickle techniques has always been a labor-intensive and time-consuming process. But this method has gotten more and more difficult over time because of multiple harvesting, requiring a large staff and expensive operating expenses. Sadly, harvesting by hand has certain difficulties, and delays can cause farmers to suffer large losses. Additionally, the current procedure requires employees to assume a crouching posture, which can cause discomfort and long-term health problems.In order to overcome these obstacles and improve the yielding of cauliflower, mechanization in this industry is needed. The use of automated harvesting methods has the capacity to decrease the duration and expenses linked with the procedure, while also mitigating the workers' pain and physical strain. The use of automation in the harvesting ofcole crops promotes better working conditions and increased productivity for farmers, all of which support the agricultural industry's sustainable growth.

The cost and time of harvesting are two important concerns that must be addressed in any developed technology, even though automated harvesting has several advantages over traditional approaches. By concentrating on reducing these variables, the created technology can show farmers how beneficial it is and get their support. The following calculations are provided to provide an estimate of the time and money saved by the developed technology in comparison to hand harvesting.

Time and cost-saving calculations

The area inhabited by humans when using the traditional harvesting technique = 0.0085 ha/h

Labour requirement for manual harvesting = 117 man-h/ha

Cost of harvesting operation by manual harvesting = $\frac{Total\ \ operating\ \ cost, Rs/h}{Field\ \ capacity\ ,\ \ ha/h}$

= 50/.0085

= 5883 Rs/ha

Labour requirement for developed harvester = 46 man-h/ha

Cost of harvesting by selective harvester = 4433 Rs/ha

Time-saving, % = $\frac{(117-46)}{117} \times 100$

= 60.6 %

Cost-saving, % = $\frac{(5883-4433)}{5883} \times 100$

= 24.6 %

3. Results and discussion

The financial aspects pertaining to the purchase and utilization of a harvester are crucial for multiple parties involved in the agricultural and farming industries. Making well-informed decisions about the acquisition, application, and upkeep of a harvester requires a thorough understanding of its cost dynamics. Purchasing a harvester represents a significant capital outlay for both farmers and agricultural businesses. Through a thorough examination of the cost economics, they are able to determine whether this investment is financially feasible and how long it will take for the enhanced productivity and improved harvesting efficiency to offset the original outlay.A thorough comprehension of the harvester's operational expenses is essential to maximize its effectiveness. This requires a detailed analysis of costs that include labour, maintenance, fuel use, and replacement parts. Equipped with this understanding, farmers may optimize their operating procedures to optimize effectiveness and save expenses. Making well-informed decisions is made easier when comparing the costs of various harvester models, taking into account aspects like productivity improvements, labour requirements, maintenance costs, and efficiency. With this method, farmers are able to choose the most economical choice that fits their own requirements.Moreover, the entire profitability of agricultural activities is directly impacted by the cost economics of a harvester. Through prudent cost control and resource optimization, farmers can increase their overall earnings and improve their financial viability. It is critical to assess the time-saving potential of harvesters since they raise overall productivity and enable longer planting cycles, which result in higher-quality agricultural output.

As seen in the study by (15) empirical evidence from the implementation of developed harvesting equipment in the harvesting of cauliflower and cabbage suggests significant cost and time savings compared to traditional manual methods. Figure 1's data highlights the useful advantages of modern procedures. Compared to traditional methods, the created technology reduced harvesting time by an astounding 60.6% and reduced overall costs by 24.6%. These results demonstrate the real benefits of adopting advanced agricultural techniques, which result in more productive and economical crop harvesting procedures. The expenses associated with owning a machine, or ownership costs, include things like insurance, taxes, interest, depreciation, and housing. These expenses depend more on how long an equipment is owned than how much it is used. On the other hand, variable costs like gasoline, oil or lubricant, labour, repair and maintenance, and other expenses are included in operating costs, which are also known as operational costs and vary according to the amount of machine utilization (19). Using the BIS code IS 9164-1979, the operational cost, break-even threshold, and payback period were calculated; the findings are shown in Table 1.

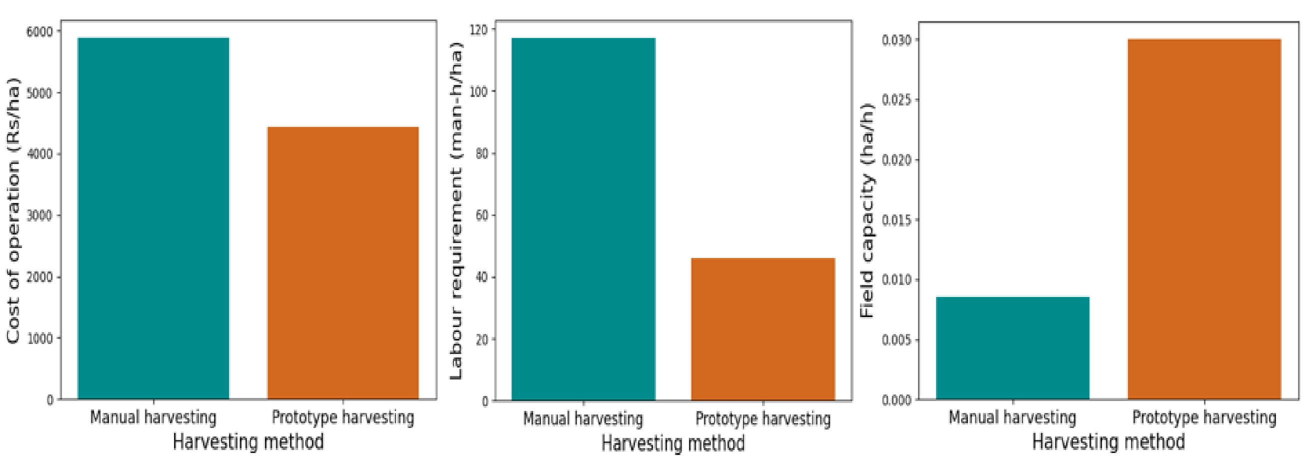

Fig. 1: Comparison of manual harvesting and prototype harvesting

Table 1. Results for cost economics of precise intelligent cauliflower harvester

Fixed cost		**Variable cost**	
Depreciation, Rs/h	37.125	Labor cost, Rs/h	50
Interest, Rs/h	16.335	Electricity, Rs/h	0.75
Housing, shelter, Rs/h	4.95	Repair and maintenance, Rs/h	24.75
Total ownership cost	**58.41**	Operating cost	**75.5**
Operating cost, Rs/h		**133**	
Total cost of machine, Rs		49500	
Field capacity, ha/h		0.0300	
Cost of operation, Rs/ha		4433	
Custom hiring charges, Rs/h		208	
Break-even point, h/year		88	
Payback period, years		3.3	
Manual avg. field capacity, ha/h		0.0085	
Manual cost of operation, Rs/ha		5883	
Saving in time		60.6 %	
Saving in cost		24.6 %	

4. CONCLUSION

The hourly operating cost of the selective cauliflower harvester with a single operator is 4433 rupees. It may be hired for 208 rupees per hour, with 88 hours a year being the break-even mark. With a predicted recovery period of 3.3 years, the investment in this harvester demonstrates financial viability and validates its profitability. It offers a striking 60.6% reduction in harvesting time and a 24.6% cost savings when compared to traditional approaches. Because of the harvester's design, significant gains in worker comfort and ergonomics are seen. Because it runs on batteries, it is compatible with eco-friendly methods and supports sustainable farming. In conclusion, the selective cauliflower harvester is a highly valuable tool in modern agriculture because it is a cost-effective, ecologically friendly, and time-efficient option.

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