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Cost-Economic Evaluation of Leafy Vegetable Harvester versus Conventional Harvesting: A Comparative Study

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The process of harvesting green vegetables is labor-intensive and costly, demanding a substantial workforce. To address the challenges associated with manual harvesting, mechanization is essential for reducing costs, saving time, and improving worker comfort. By precise and

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comprehensive evaluations of ownership and operational expenses, farmers can acquire valuable information. This knowledge empowers them to make well-informed decisions about purchasing new machinery, optimizing existing equipment, or even exploring alternative methods to enhance their farm's productivity and financial outcomes. Therefore, a battery-operated leafy vegetable harvester is compared with manual harvesting in terms of cost economics. The present results reveal that the ownership and operating costs of the developed harvester are 76.86 Rs/h and 83.702 Rs/h. Compared to traditional methods, it saves an impressive 85.71% of the time and reduces costs by 54.12% during harvesting. The study determined that using battery-operated leafy vegetable harvesters is not only more cost-effective than manual harvesting but also environmentally friendly when compared to fuel-operated harvesting methods.

Keywords: Break-even point; cost economics; operating cost; ownership cost; payback period.

1. INTRODUCTION

Fuel-operated machines like combine harvesters emit harmful gases such as CO, and CO_2 which have a significant impact on climate change [1]. Climate change affects agricultural practices and crop yields. Therefore, efficient and sustainable use of technology can help to reduce their environmental impact. Over the last decade, the global Electric Vehicles market has boomed, driven by its carbon-free nature. With increasing pressure to achieve net-zero emissions, EVs are playing a crucial role in combating climate change, improving public health, and reducing ecological damage [2].

Machinery and equipment play a crucial role on farms, enabling various tasks to be accomplished efficiently. However, these essential tools come with a significant price tag. In recent years, the costs associated with farm machinery and equipment have been on the rise. There are several reasons for this trend, such as the introduction of larger machines that can handle more work, the incorporation of advanced technology in new models, increased prices for replacement parts, and higher energy costs required to power these machines. Despite these escalating costs, successful farmers have shown that it is possible to manage and control machinery expenses effectively. By adopting smart practices and prudent decision-making, they can keep the costs per acre within manageable limits. This ability to control machinery costs is a critical aspect of running a profitable farm. One of the key challenges for farmers is deciding when to invest in new machinery and when to trade in older equipment. Making such decisions wisely necessitates a clear understanding of the complete costs involved in owning and operating farm machinery. This entails considering not only the upfront investment but also taking into account the ongoing costs involved in maintenance, repairs, fuel, and other operational aspects. By conducting accurate and thorough assessments of these ownership and operational costs, farmers can gain valuable insights. With this knowledge, they can make informed choices about acquiring new machinery, optimizing their current equipment, or even exploring alternative approaches to improve their farm's productivity and financial performance. Mechanized agriculture refers to the utilization of machinery in farming activities, which significantly boosts the productivity of farm workers. By adopting mechanized power for agricultural purposes, farmers can reduce the physical strain and difficulties associated with traditional manual practices. Additionally, this approach accelerates agricultural processes, reduces expenses, and ultimately enhances overall productivity. In many developing nations, the manual harvesting operation, which involves using sickles, is a common practice. However, this method is time-consuming and demands a considerable amount of labor. Transitioning to mechanized harvesting can address these challenges and bring about notable improvements in the agricultural sector. Research has indicated the significant influence of agricultural mechanization on advancing high-quality agricultural development [3]. For instance, the implementation of mechanized sowing and management techniques in the field contributes to more even crop distributions and fosters growth [4]. Moreover, employing agricultural machinery has been shown to minimize agricultural losses and enhance product quality [5]. The design intricacies of a harvester are influenced by various factors. These factors comprise the plant's structure and arrangement, the intended use of the harvested crop (whether for human or animal consumption), and the agronomic characteristics of the crop [6-9] Additionally, other essential considerations are the ergonomic aspects, as well as the prevailing

soil and weather conditions during the harvesting process, and various operational parameters.

2. METHODOLOGY

The developed leafy vegetable harvester's total cost is calculated based on the bill of materials and the cost of fabrication which is considered 25% of the total cost. The total cost thus obtained is ₹65,150 (P). The following assumptions were considered for determining the cost of operation of battery-operated leafy vegetable harvester.

- Useful life hours of machine per year (H): 200 hours
- Useful life years of machine (L): 6 years
- Salvage value (S): 10 percent of the initial cost
- Interest rate (i): 12 percent of the initial cost
- Shelter and insurance: 2 percent of the initial cost
- Price of electricity: 0.615/h
- Labour wages: 400 Rs day-1 (8 hours)
- Depreciation method: Straight line method

2.1 Machinery Cost

The two main cost categories for farm equipment are ownership costs and operational costs. Annual ownership expenses are incurred regardless of how often a machine is used while operating costs change in direct proportion to how frequently a machine is used [10]. Before the equipment gets sold or worn out, the real cost of these expenses cannot be determined. But by applying a few assumptions regarding equipment life, annual use, and fuel and labour prices, the expenses can be roughly calculated. This document includes a worksheet that can be used to determine expenses associated with a certain machine or process. Depreciation, interest (also known as opportunity cost), taxes, insurance, and housing are all considered ownership expenses (also known as fixed costs). Repairs and maintenance, gasoline, lubricant, and labour costs for operators are all considered operating costs (also known as variable costs).

2.1.1 Ownership cost

Ownership costs, or fixed costs, are the expenses that owners have to pay regularly for owning something. Depreciation, interest (opportunity cost), taxes, insurance, and housing the item or property are a few examples of these costs.

2.1.1.1 Depreciation (D)

Depreciation is an expenditure associated with a machine's wear, deterioration, and age. The actual value of a machine when traded or sold can vary depending on its mechanical wear, either being somewhat higher or lower than the typical values for the same kind of equipment. Moreover, technological advancements or significant changes in design can render older machines obsolete, resulting in a sharp decline in their remaining value. However, the most crucial factors in determining a machine's remaining value are typically its age and the total accumulated hours of use. An economic lifespan for the machinery and the value of salvage at the end of its commercial lifespan must be given before an estimate of annual depreciation can be calculated. The number of years over which costs must be estimated is known as the economic life of a machine. Since most farmers exchange equipment for a new one before it is entirely worn out, it is frequently shorter than the machine's service life. A lifespan of 10 to 12 years for the majority of farm equipment and 10 years for tractors as a general rule of thumb, the useful life harvester in this case is 6 years. Salvage value refers to an estimated monetary worth assigned to a machine upon reaching the conclusion of its economic life. This value represents the prospective amount that could be obtained through options such as a trade-in allowance when exchanging the machine for a new one, the anticipated value in the used market if the machine is to be sold outright, or a value of zero if the intention is to retain the machine until it is fully depreciated and no longer functional.

The annual depreciation value can be calculated by the following expression

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

Salvage value (S) =10 percent of the initial cost
=0.10×65150
=6515 Rs

Where,

D = Depreciation (Rs h-1)
P = Initial cost (Rs)

$D=\frac{65150-6515}{6\times200}$ =48.86 Rs/h

Depreciation of developed harvester = 48.86 Rs/h…… (1)

2.1.1.2 Interest (I)

When a farmer is considering purchasing a harvester for the farm, there are two main ways to finance the acquisition: borrowing money from a lender or using the farmer's own capital. If the farmer decides to borrow, the interest rate will be determined by the lender based on factors like creditworthiness and market conditions. On the other hand, if the farmer chooses to use their own funds, the interest rate should be based on the opportunity cost of that capital in other potential investments within the farm business. In cases where a combination of borrowing and using own capital is utilized, a weighted average of the two interest rates should be considered. For the purpose of financing the designed harvester, let's use an average interest rate of 12 percent. Annual interest is calculated on an average investment by using the prevailing interest rate by the following formula:

$$I = \frac{P+S}{2} \times \frac{i}{H}$$

$$I = \frac{65150+6515}{2} \times \frac{12}{100\times200}$$

$I = 21.4995$ Rs h^{-1}

Interest on developed harvester = 21.49 Rs/h…… (2)

2.1.1.3 Taxes, housing, and insurance

These additional costs, namely sales tax, road tax, insurance, and shelter charges, though relatively smaller compared to depreciation and interest, should not be overlooked when considering the overall expenses of owning farm machinery like a harvester. Sales tax and road tax can be distributed over the machine's life to account for their impact on the annual cost. Insurance is essential for safeguarding the machinery against disasters, theft, and damage, ensuring that the farmer can replace or repair it if needed. Providing proper shelter, tools, and maintenance equipment for the machinery reduces the need for frequent repairs in the field and protects it from weather-induced wear and tear, resulting in greater reliability during operations and a higher trade-in value. The aggregate expenses for taxes, insurance, and housing can be estimated at approximately 2% of the average machine cost annually, taking into account insurance and shelter costs that typically amount to around 1% of the initial purchase cost of the machinery per year.

Taxes, Housing, and Insurance = (2 % of P)/H

$= \frac{0.02\times65150}{200}$

Taxes, Housing, and Insurance on developed harvester = 6.515 Rs h^{-1}…… (3)

Total ownership cost = (1) + (2) + (3)

= 48.86 + 21.49 + 6.51

Total ownership (Rs/h) = 76.86..... (4)

2.1.2 Operating cost

Variable costs are those expenses that are directly connected to the volume of use. These expenses only come into play while the machine is in use. Repairs, fuel and lubricants, servicing, and labour expenditures are all examples of variable costs.

2.1.2.1 Repair and maintenance costs

Repair costs for farm machinery happen because the machines need regular maintenance, parts wear out over time, and sometimes accidents can cause damage. The amount of money needed for repairs can vary a lot depending on where the farm is located, the type of soil, rocks, weather, and how the machines are used. Even on neighboring farms, repair costs may be different because of how they manage their machines and the skills of the people operating them. The best way to know how much repairs will cost is by keeping track of past repair expenses. By having good records, the owner can see if a machine has needed more or less repairs than usual and when it might need a major overhaul. These records also tell him how well his maintenance program is working and how good he is at fixing things. If he doesn't have these records, he can still estimate repair costs based on average experiences, but it may not be as accurate for your specific situation. Repair and maintenance costs are an essential part of machinery ownership. Repairs and maintenance cost was taken at 10 % of the machine's purchase price per year.

Repair and maintenance cost = (0.10×65150)/200
=32.57

Repair and maintenance cost of developed harvester =32.57 Rs/h……. (5)

2.1.2.2 Labour wages

For jobs like planting or harvesting, various-sized machinery needs varied numbers of labour, so it's crucial to take labour costs into account while analyzing machinery. When contrasting ownership with customized hiring, labour costs are a crucial factor as well. The labour wages were calculated from the actual labour charge paid in rupees per day at the prevailing rates in the study area. Rs. 400/day is paid for the leafy vegetable harvester operator, single labor was engaged for harvesting operation @ Rs. 400/ day 8 hours taken per day.

Labour wages =400/8 =50

Operator wages for developed harvester = 50 Rs/h…… (6)

2.1.2.3 Electricity

India has had relatively lower electricity tariffs compared to many developed countries. Electricity cost is determined by the product of charging power and the time needed for charging. The charging power is derived from the product of charging voltage and charging current. A standard rate for power usage per unit is considered. The total units required by various components are recorded, and the overall electricity charges are calculated based on these measurements.

Total electricity charges = 1.132 Rs/h…….. (7)

Total operating cost = (5) + (6) + (7)
= 32.57+50+1.132
= 83.702 Rs/h (8)

The total cost of the developed harvester = Total ownership cost+ Total operating cost

Total cost of the developed harvester = 76.86 + 83.702 ≈ 160.567 Rs/h

2.2 Harvester Cost of Operation/ha

The field capacity of the developed harvester = 0.07 ha/h

Cost of operation/ha = 160.57/0.07 =2293.81 Rs/ha……. (9)

Overhead charges @25% of total cost = 160.56×0.25 =40.14 Rs/h

Profit = Overhead charges + 25% of overhead charges
= 40.14 +10.03
= 50.17 Rs/h

2.3 Custom Hiring Charges (CHC)

Custom hiring charges for agricultural machines refer to the personalized and formal fees for renting specific farming equipment. These charges are calculated to suit the particular needs of farmers when they hire machines for their agricultural tasks. The hiring cost of agricultural machines is determined based on factors like the type of machine required (such as tractors, harvesters, or plows), the length of time it will be rented, additional services needed, and the location where it will be used. Each rental agreement is unique, and the charges are calculated accordingly to provide a suitable and formal arrangement for the farmer's specific needs.

Custom hiring charges = Total cost + Overhead charges + Profit
= 160.567+40.14+ 50.17
= 250.877 Rs/h

2.4 Breakeven Point

The level of operation or output at which a harvester's total running expenses are equal to its total revenue from use is known as the harvester's break-even point. At this point, there is no profit or loss, and the business is covering all its costs without making additional gains. The break-even point is a crucial concept in business and is often used to analyze the financial viability of investments and operations. For a harvester, the break-even point is reached when the total revenue generated from the harvested crops (or any other service provided by the harvester) exactly covers all the costs associated with owning, maintaining, and operating the machine.

$$\text{Breakeven point (h)} = \frac{\text{Annual fixed cost /year}}{\text{Custom hiring charges} - \text{Operating cost}}$$

$$= \frac{76.86 \times 200}{250.87 - 83.70}$$

= 91.95 h/year

Average net annual profit (Rs) = (CHC-operating cost) × Annual use
= (250.877-83.70) ×200
=₹ 33, 435

2.5. Payback Period

The payback period of a harvester is the timeframe required for the total cash inflows generated by using the harvester to equal the initial investment cost of purchasing the machine. In simpler terms, it is the time it takes for the harvester to "payback" the money spent on its purchase through the revenue it generates. An important financial indicator used to evaluate the risk and return of an investment is the payback period. In general, an earlier payback time is preferable because it signals a quicker return on investment and lowers the possibility of a drawn-out recovery phase.

$$\text{Payback period} = \frac{\text{Intial cost of machine}}{\text{Average net annual profit}}$$
= 65150/33435
= 1.94 Years

2.6 Conventional Harvesting vs Mechanized Harvesting

Due to labour shortages during the busiest harvesting season, harvesters are the most widely used agricultural machinery in India [11]. Harvesting leafy vegetables has traditionally been a labor-intensive and time-consuming task, relying on manual methods involving the use of a sickle. However, this practice has become increasingly burdensome, demanding a significant amount of manpower and leading to high operational costs. Unfortunately, the manual approach is not without its challenges, as delays in harvesting can result in substantial losses for farmers. Furthermore, the current method requires workers to sit in a squat position, causing discomfort and potential health issues over time. To address these issues and improve the efficiency of leafy vegetable harvesting, there is a pressing need for mechanization in this sector. Implementing mechanized harvesting techniques can help reduce both the time and cost associated with the process, while also alleviating the discomfort and strain experienced by workers. Embracing automation in leafy vegetable harvesting would not only enhance productivity and profitability for farmers but also promote better working conditions and contribute to the sustainable growth of the agricultural industry.

Mechanical harvesting offers numerous advantages over manual harvesting, but two major issues that any developed technology should address are the harvesting cost and harvesting time. By focusing on reducing these factors, the developed technology can prove its effectiveness and appeal to farmers. To quantify the time and cost saved by the developed technology compared to manual harvesting, the following calculations are presented below

Saving in time

Area covered by man in the conventional method of harvesting = 0.01 ha/h

Man, hours in the conventional method of harvesting/ha = 100 h

The field capacity of the developed harvester = 0.07 ha/h

Man, hours with the mechanized method of harvesting/ha = 14.28 h

$$\text{Saving in time (\%)} = \frac{100-14.28}{100} \times 100$$
=85.72%

Saving in cost

Man, hours in the conventional method of harvesting/ha = 100 h

Labour wages = 400 Rs/day (8 hours)

Total cost in the conventional method of harvesting/ha = (400/8)×100
= 5000 Rs/ha

The total cost of operation with a developed leafy vegetable harvester =2293.81 Rs/ha

$$\text{Saving in cost (\%)} = \frac{5000-2293.81}{5000} \times 100$$
=0.5412×100
=54.12%

3. RESULTS AND DISCUSSION

The cost economics of a harvester holds paramount importance for various stakeholders engaged in agriculture and farming. Making well-informed decisions about the purchase, operation, and maintenance of a harvester hinges on a thorough understanding of its cost dynamics. For farmers and agricultural businesses, procuring a harvester represents a

substantial capital investment. By analyzing the cost economics, they can determine the financial feasibility of the investment and assess the time required to recoup the initial outlay through improved harvesting efficiency and increased productivity. Understanding the operating costs associated with the harvester is critical for optimizing its efficiency. This includes assessing expenses such as fuel consumption, maintenance, labor, and spare parts. With this knowledge, farmers can fine-tune their operational practices to maximize efficiency and minimize costs. Cost comparison between different harvester models or types enables farmers to make well-founded choices. By evaluating factors like efficiency, labor requirements, maintenance expenses, and potential productivity gains, they can select the most cost-effective option that aligns with their specific needs. Moreover, the cost economics of a harvester directly impacts the overall profitability of agricultural operations. By keeping costs in check and optimizing resource utilization, farmers can increase their overall profits and financial sustainability. Evaluating the time-saving potential of harvesters is crucial, reducing harvesting time not only enhances overall productivity but also allows for increased planting cycles, resulting in better agricultural output.

It was found that the use of developed technology for harvesting leafy vegetables resulted in significant cost and time savings compared to traditional manual methods. Similar trends are seen in the evaluation of sugarcane combine harvesters [12]. The data depicted in the figure provides compelling evidence of the technology's benefits. Specifically, the developed technology outperformed the traditional methods by reducing harvesting time by an impressive

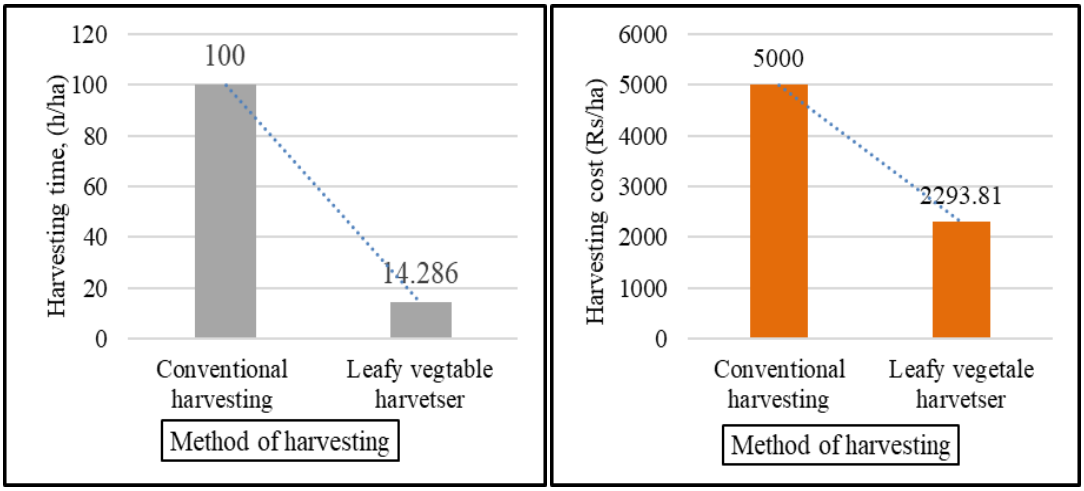

Fig. 1. Comparison of harvesting time and cost with the method of harvesting

Table 1. Results for cost economics of battery-operated leafy vegetable harvester

Ownership cost		**Operating cost**	
Depreciation, Rs/h	48.86	Labor cost, Rs/h	50
Interest, Rs/h	21.49	Electricity, Rs/h	1.132
Housing, shelter, Rs/h	6.515	Repair and maintenance, Rs/h	32.57
Total ownership cost	**76.865**	Total operating cost	**83.702**
Total cost of operation, Rs/h		**160.567**	
Field capacity of developed harvester, ha/h		0.07	
Cost of operation/ha		2293.81	
Overhead charges, Rs/h		40.14	
Profit, Rs/h		50.17	
Custom hiring charges, Rs/h		250.877	
Break-even point h/year		91.95	
Payback period, years		1.94	
Saving in time		85.71%	
Saving in cost		54.12%	

85.71% and cutting down overall costs by 54.12%. These findings underscore the practical advantages of adopting advanced techniques in agricultural practices, leading to more efficient and cost-effective crop harvesting processes. Ownership costs are related to owning the machine and include factors such as depreciation, interest, taxes, shelter, and insurance. These costs are determined by the duration of machine ownership rather than the extent of usage. On the other hand, operating cost costs, also known as operational costs, vary based on the level of machine usage. Variable costs include expenses like repair and maintenance, fuel, oil or lubrication, and labor costs [13]. To calculate the operational cost, break-even point, and payback period, the bis code is: 9164-1979 was used. The results obtained in cost economics are presented in the following table.

4. CONCLUSION

The leafy vegetable harvester operates with a single operator and costs 2293.81 rs per hour to run. It can be hired by customers for 250.87 Rs per hour, and its break-even point is at 91.95 Rs per hour. Within 1.94 years, the investment in this harvester can be recovered, making it a profitable choice. Compared to traditional methods, it saves an impressive 85.71% of the time and reduces costs by 54.12% during harvesting. Additionally, the harvester improves the working posture of laborers, ensuring better ergonomics and comfort. Its battery-operated design also makes it environment-friendly, contributing to sustainable agriculture practices. In conclusion, the leafy vegetable harvester is not only a time and cost-efficient option but also enhances worker comfort and upholds environmental responsibility, making it a valuable asset for modern agriculture.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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