Sustainable Harvesting Methods for Wheat Crop: A Comparative Economic and Performance Analysis

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Abstract:

This research paper addresses "Sustainable Harvesting Methods for Wheat Crop: A Comparative Economic and Performance Analysis," focusing on India's agricultural efficiency and food security. It compares traditional manual wheat harvesting using sickles with the modern self-propelled reaper binder harvester. Employing a completely randomized design, critical parameters like crop characteristics, crop condition, field capacity, field efficiency, grain losses, fuel consumption, and labor requirements were analyzed. Wheat crop characteristics observed included an average height of 73.44 cm, 342 plants per m2, 34 g grain quantity per crop, 10% grain moisture content, 19.5% straw moisture content, and a grain-straw ratio of 1.56.

Results revealed the self-propelled reaper binder's superiority, showing higher field capacity and efficiency, lower grain losses, reduced labor requirements, and cost-effectiveness compared to manual harvesting. The reaper binder's effective field capacity ranged from 0.305 ha/h to 0.426 ha/h, while manual harvesting relied on man-hours per hectare. Field efficiency for the reaper binder ranged from 75.30% to 79%, surpassing manual harvesting. Moreover, the reaper binder exhibited decreased grain losses due to pre-harvest, shattering, and windrowing losses compared to manual methods. Fuel consumption ranged from 1.301 L/h to 1.92 L/h, with higher rates at higher speeds. Labor requirements were significantly reduced for the reaper binder, employing only one skilled laborer compared to 83 workers for manual harvesting.

The cost analysis demonstrated the self-propelled reaper binder's viability, costing 21,427.07 per hectare and 516.60 per hour at an average speed of 3.5 kmph. These findings advocate adopting sustainable harvesting practices to enhance wheat farming productivity and ensure India's future food security.

Keywords: Food security, manual harvesting, self-propelled reaper binder, field capacity, grain losses, cost analysis.

1. Introduction:

India, as one of the vast countries in the world, faces the challenge of feeding its mammoth population due to a population growth rate that outpaces the growth rate in food grain production. With approximately 329 million hectares of geographical area, of which about 166 million hectares are cultivated land, ensuring food security becomes a pressing concern. However, the net area sown stands at around 142 million hectares, indicating the need for increased agricultural efficiency to meet the food demands of a growing population (Narula,2013).

In this pursuit of feeding the nation, sustainable agricultural practices and technological advancements play a pivotal role. To optimize wheat crop production, it is essential to utilize improved agricultural implements that can significantly increase the output of farming operations in the country. This includes the introduction of high-yielding varieties, development of irrigation facilities, efficient use of chemicals, fertilizers, insecticides, and agricultural mechanization. Agricultural mechanization has proven to be a crucial factor in enhancing farm productivity, reducing drudgery for laborers, and improving economic returns for farmers (Amare and Endalew, 2016). Among the major components of agricultural mechanization, tractors and associated farm equipment like tillers, disc harrows, seed drills, and harvesters play a vital role in transforming the agriculture sector.

However, despite significant advancements in the green revolution, there remains a need for continuous research and development in various domains, particularly in agricultural machinery (Conway, 2019). One specific focus area is the harvesting and threshing operations for wheat crops, which can have a profound impact on overall productivity and economic viability.Traditionally, manual labor using sickles has been the primary method for harvesting wheat crops (Hasan et al., 2020). However, the non-availability of laborers often leads to delayed harvesting, leaving the crops susceptible to adverse weather conditions. Timely harvesting is critical to minimizing grain and straw losses caused by over-maturity. Therefore, there is an urgent need to adopt modern harvesting equipment and methods that can ensure timely and efficient crop harvesting (Mohanta et al., 2015).

Efforts to develop harvesting equipment in India began in the early 1960s, with attempts to design animal-drawn and engine-driven reapers. While the initial machines did not gain widespread popularity, subsequent developments led to the creation of tractor-mounted PTO operated self-raking type reapers. Despite progress, the full potential of agricultural mechanization for wheat harvesting is yet to be harnessed. With the central focus on "Comparative Evaluation of Performance of Harvesting Methods for Wheat Crop," this research paper aims to assess different combinations of harvesting methods for wheat crops and delve into the economic implications of each approach. To achieve these objectives, we will thoroughly investigate various performance parameters and economic considerations associated with each harvesting method. Through rigorous data analysis and evaluation, we endeavor to offer valuable insights into the potential benefits of adopting sustainable harvesting practices in the wheat farming sector.

By contributing to the advancement of agricultural mechanization and promoting the utilization of modern agricultural implements, we aspire to play a significant role in mitigating challenges posed by the burgeoning population and ensuring a stable and secure food supply for India's future. Our research endeavors to align with broader efforts towards achieving food security and fostering sustainable agricultural development, making meaningful contributions to the nation's agricultural landscape.

2. Materials and Methods:

2.1 Study Design:

This research paper presents a meticulous study titled "Sustainable Harvesting Methods for Wheat Crop: A Comparative Economic and Performance Analysis." The experiment was conducted using a completely randomized design (CRD) with three replications, ensuring robustness and reliability in the data obtained. The field operations were carried out at the farm of IFTM, where wheat crops were strategically subjected to different harvesting methods to assess their performance and economic viability.

2.2 Harvesting Methods:

The study encompassed two distinct treatments, each representing a specific harvesting method:

a) Treatment 1 (TI): Manual harvesting utilizing traditional serrated sickles.

b) Treatment 2 (T2): Implementation of a self-propelled reaper binder harvester, representing a mechanized approach to wheat crop harvesting.

2.3 Description of Harvesting Machineries:

2.3.1 Serrated Sickle:

The manual harvesting treatment involved the utilization of traditional serrated sickles, time-honored harvesting tools in the agricultural sector. These sickles consist of a metallic blade, skillfully crafted with sharp teeth, and a sturdy wooden handle. Precise measurements and specifications, including overall dimensions, weight, cutting edge length, radius of curvature, number of teeth per centimeter, and pricing, were diligently recorded to ensure an accurate analysis given at table 2.1

Table 2.1: Specifications and Working Features of Serrated Sickle

Sl. No.	Particulars	Unit	Specification
1	Overall Dimensions	mm	465 x 55 x 40
2	Weigh	kg	0.257
3	Cutting Edge Length	mm	255
4	Radius of Curvature	mm	260
5	Number of Teeth	per cm	5
6	Price	Rs.	25

2.3.2 Self-propelled Reaper Binder:

Treatment 2 employed a self-propelled reaper binder harvester, which signifies a remarkable leap towards mechanization in the wheat crop harvesting process. This cutting-edge machine is characterized as hand-guided, walking-type, lightweight, and powered by a robust 10.2 hp diesel engine. The intricate components of the reaper binder include a cutter bar assembly, power transmission unit, straw collector, binding twines, and various other essential mechanisms. Detailed examination and analysis of the main parts and their functions were meticulously conducted to comprehend their impact on performance.

2.4 Performance Evaluation of Harvesting Methods:

Performance evaluation constituted a pivotal aspect of this study, which involved the systematic analysis of various critical parameters. The independent variables assessed were crop moisture content and forward traveling speed. The dependent variables under scrutiny included:

a) Effective Width of Coverage: Determining the width of the implement's cut in the wheat field, providing insights into its efficiency.

b) Harvesting Losses: Categorizing and quantifying pre-harvest losses, shattering losses, and windrowing losses to gauge the overall efficiency of each harvesting method.

c) Field Capacity: Accurately measuring the rate at which the machine performs its primary function, i.e., the number of hectares it can harvest per hour.

d) Field Efficiency: Calculating the ratio of effective field capacity to theoretical field capacity, shedding light on the machines' practical performance in the field.

e) Actual Working Time: Rigorously measuring and analyzing the actual operating time of each implement in the wheat field, factoring in any time losses due to turning or breakdowns.

f) Fuel Consumption: Precisely determining the amount of fuel consumed by implement per unit time and area, vital in understanding the economic implications of the harvesting methods.

2.5 Cost Economics:

A comprehensive analysis of cost economics formed a crucial part of this research endeavor. The total cost of performing field operations was meticulously computed, considering both fixed and variable costs. The fixed costs comprised depreciation, interest, insurance, taxes, and housing charges. On the other hand, variable costs encompassed repair and maintenance cost, labor charges, fuel cost, and lubrication cost (Swain et al., 2020). These calculations were performed meticulously to ascertain the true economic implications of each harvesting method.

2.6 Data Analysis:

The data collected from the various parameters and variables underwent a rigorous statistical analysis. Advanced statistical methods were applied to compare and contrast the performance and economic aspects of different harvesting methods for wheat crops. The results were scrutinized and interpreted to derive meaningful insights, aiding in the formulation of sustainable agricultural practices and promoting enhanced food grain production.

2.7 Experimental Set-up and Data Collection:

To ensure the reliability and precision of the results, the experiment was meticulously replicated three times. Samples were systematically collected from standing crops, grains, outlets, chaff, and sieve outlets during the harvesting operations. These samples were carefully separated and weighed in the laboratory, enabling accurate assessment of losses and efficiencies. Moreover, a specific area of twenty meters in length, with the width of the implement, was thoughtfully selected for harvesting and in-depth investigation. Thorough sampling and precise data collection were conducted for each treatment, leading to comprehensive and reliable outcomes.

3. Results

3.1 Crop Characteristics of Wheat:

The wheat crop used for the experiment was grown at the IFTM farm, and data were collected for Treatments T1, T2, and T3. The crop characteristics observed in the wheat field during the study are summarized in Table 3.1.

Table 3.1 Crop Characteristics of Wheat

S. No.	Appearance	Standing crop
1	Average height of plant, cm	73.44
2	Average number of plant per m2	342

3	Average quantity of grain per crop, g	34
4	Average moisture content of grain, %	10
5	Average moisture content of straw, %	19.5
6	Grain-straw ratio	1.56

During the study, the standing wheat crop exhibited specific characteristics: an average height of 73.44 cm, a density of approximately 342 plants per square meter, and an average grain quantity of 34 grams per crop. The grain had an average moisture content of 10%, while the straw had an average moisture content of 19.5%. The grain-straw ratio was calculated to be 1.56. These crop characteristics are crucial in assessing the crop's health, maturity, and potential yield, providing valuable information for further analysis and comparison between different harvesting methods.

3.2 Performance Evaluation of the Harvesting Machineries:

3.2.1 Manual Method: The average height of cut for the wheat crop was recorded at 39 mm, which is a crucial factor in determining the stage of maturity and the potential grain losses during harvesting. Speaking of grain losses, the study revealed significant pre-harvest losses of 56.40 kg/ha, shattering losses of 45.35 kg/ha, and windrowing losses of 36.20 kg/ha, resulting in a total loss of 137.95 kg/ha. These findings underscore the importance of timely and efficient harvesting to minimize grain losses and enhance overall productivity. Additionally, labor requirement was measured at 83 man-hours per hectare, signifying the considerable manual effort needed in traditional harvesting methods.

3.2.2 Self-propelled Reaper Binder: The performance characteristics of the self-propelled reaper binder were evaluated under different parameters, including speed of operation, crop moisture content, field capacity, field efficiency, harvesting losses, fuel consumption, and labor requirement.

1. Speed of Operation: The speed of operation was considered as an independent variable to study its impact on various performance parameters, such as height of cut, grain losses, field capacity, and fuel consumption. The speed of operation was tested at 3.75 kmph, 4.00 kmph, and 4.25 kmph.
2. Crop Moisture Content: Both the reaper binder and manual harvesting methods were evaluated for their crop moisture content. The moisture content for the reaper binder and manual method ranged from 20%, 18%, and 16%, with a corresponding height of cut for the manual method at 3.9 cm, 4.1 cm, and 3.7 cm, respectively.

3. Field Capacity: The results of the effect of speed and moisture content on the effective field capacity of the self-propelled reaper binder for wheat crop are presented in Figure 3.1. It is evident that the effective field capacity increases with the forward speed of traveling.

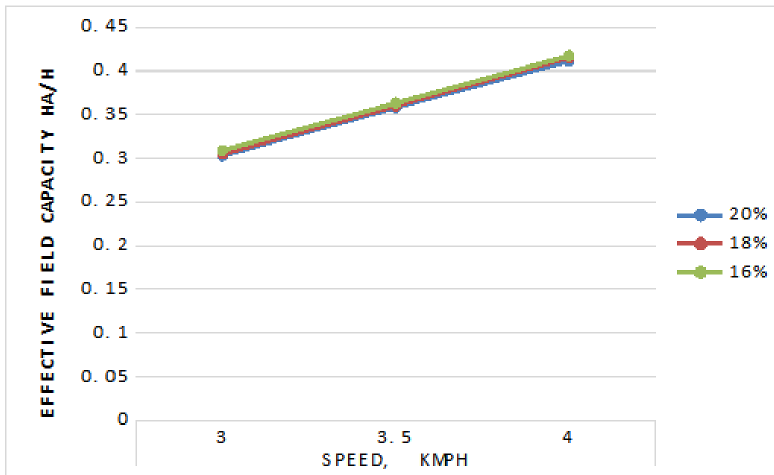


Figure 3.1 - Effect of speed and moisture content on actual field capacity of the self-propelled reaper binder.

4. Field Efficiency: The field efficiency of the self-propelled reaper binder at different moisture content levels and speeds is shown in Figure 3.2. The field efficiency was found to increase with the forward speed of traveling.

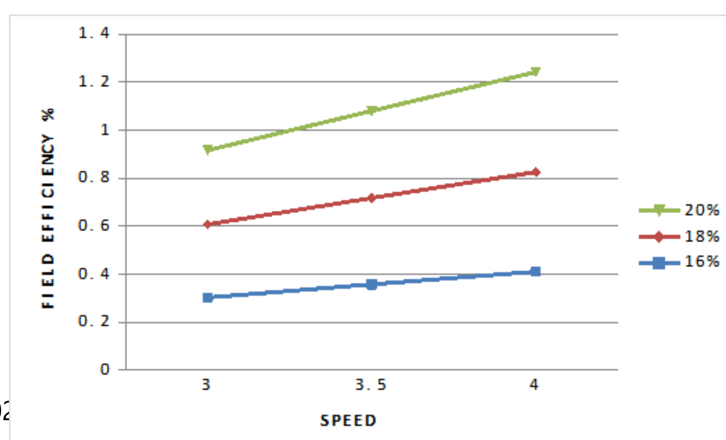


Figure 3.2 - Effect of speed and moisture content on field efficiency of the self-propelled reaper binder.

5. Grain Losses: Pre-harvest losses were influenced by moisture content, while shattering and windrowing losses were affected by forward traveling speed.

a. Pre-harvest losses: The pre-harvest losses were found to be 56.40 kg/ha, 55.56 kg/ha, and 54.20 kg/ha, or 3.25%, 3.47%, and 3.38%, at moisture content levels of 20%, 18%, and 16%, respectively.

b. Shattering losses: Shattering losses varied with the forward traveling speed and moisture content. The shattering losses were highest at 4.00 kmph and decreased at 3.00 kmph. At the highest speed, the shattering losses were 52.81 kg/ha, 55.18 kg/ha, and 56.53 kg/ha for 20%, 18%, and 16% moisture content, respectively as shown in fig 3.3.

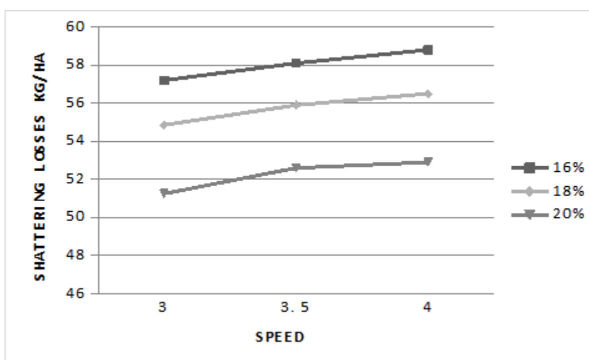
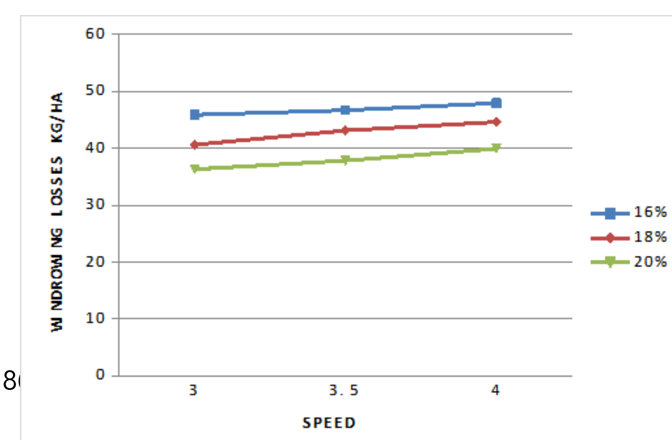


Fig 3.3 Effect of speeds and moisture content on shattering losses of self-propelled reaper binder.

c. Windrowing losses: Windrowing losses also increased with the forward speed of traveling and moisture



content. At 4.00 kmph, the losses were 39.46 kg/ha, 44.58 kg/ha, and 47.61 kg/ha for 20%, 18%, and 16% moisture content, respectively as shown in fig 3.4.

Fig. 3.4 Effect of speed and moisture content on windrowing losses of self-propelled reaper binder.

6. Fuel Consumption: Fuel consumption data at different operating speeds of the harvester are provided in Figure 3.5. The minimum fuel consumption was recorded at the lowest operating speed of 3.00 kmph, while the maximum fuel consumption was observed at the highest speed of 4.00 kmph.

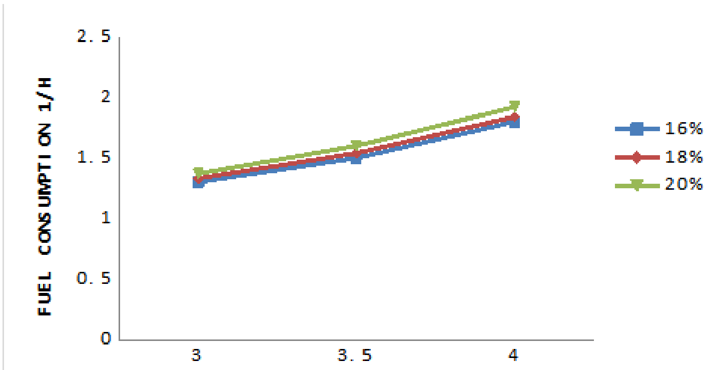


Figure 3.5 - Fuel consumption on the effect of the speed of the self-propelled reaper binder.

7. Labor Requirement: Labor requirements for different activities, including operating the reaper binder and manual harvesting, were assessed. Skilled labor was required to operate the reaper, while unskilled labor was needed for field preparation, manual harvesting, collection, and bundling of the crop.

3.5 Cost Economics:

The cost analysis of the machine was carried out, and the total cost of operating the self-propelled reaper binder was found to be 21,427.07 per hectare and 516.60 per hour at an average speed of 3.5 kmph. Assuming the harvester would be used for about 350 hours per year.

The cost of manual harvesting, including labor wages, was calculated separately. The cost for one hectare area in UP, considering labor wages of 300/day per labor, and the requirement of 83 workers for harvesting one hectare area in a single day, resulted in a cost of 24,900 for per hectare area.

4. Discussion:

The results obtained from the comparative performance evaluation of different harvesting methods on wheat crop revealed valuable insights into their respective efficiencies and economic implications. The following key observations were made:

1. The self-propelled reaper binder demonstrated higher effective field capacity compared to the manual method. It showcased the potential to cover more hectares in an hour, increasing the overall productivity.
2. Field efficiency was higher with the self-propelled reaper binder at higher operating speeds, indicating its superiority in efficiently harvesting the crop.
3. The self-propelled reaper binder exhibited increased fuel consumption at higher speeds, emphasizing the importance of optimizing speed for cost-effectiveness.
4. Manual harvesting resulted in higher grain losses due to shattering and windrowing, highlighting the advantage of mechanized methods in minimizing losses.
5. Labor requirements were significantly reduced with the self-propelled reaper binder, indicating the potential for labor savings and enhanced efficiency.
6. Cost analysis revealed that, despite the initial investment, the self-propelled reaper binder offered a viable and economically feasible alternative to manual harvesting in the long run.

Overall, the results suggest that the implementation of the self-propelled reaper binder can substantially enhance wheat harvesting efficiency and reduce losses, thereby contributing to increased crop productivity and improved economic viability for farmers. However, further studies and large-scale field trials are recommended to validate the results and assess the practical feasibility of adopting mechanized harvesting methods on a broader scale.

5. Conclusion

The study focused on addressing India's challenge of ensuring agricultural efficiency and food security for its growing population. By comparing traditional manual harvesting using sickles with the modern self-propelled reaper binder harvester, the research aimed to identify optimal harvesting methods that can enhance wheat crop production. The results demonstrated the superiority of the self-propelled reaper binder over manual harvesting, showcasing higher field capacity, efficiency, and cost-effectiveness, along with reduced grain losses and labor requirements. These findings underscore the significance of adopting mechanized harvesting techniques to optimize wheat farming productivity and contribute to India's sustainable agricultural development. The research's implications are invaluable in guiding policymakers and stakeholders towards promoting advanced agricultural mechanization, thus paving the way for a more secure and stable food supply for the nation's future.

References

Amare, D. and Endalew, W., 2016. Agricultural mechanization: Assessment of mechanization impact experiences on the rural population and the implications for Ethiopian smallholders. Engineering and Applied Sciences, 1(2), pp.39-48.

Conway, G., 2019. The doubly green revolution: food for all in the twenty-first century. Cornell University Press.

Hasan, K., Tanaka, T.S., Alam, M., Ali, R. and Saha, C.K., 2020. Impact of modern rice harvesting practices over traditional ones. Reviews in Agricultural Science, 8, pp.89-108.

Mohanta, R.K., Sadangi, B.N., Sarangi, D.R. and Prasad, S.M., 2015. Krishi Vigyan Kendra Cuttack. Performance-cum-Impact 2010-15.

Narula, S., 2013. The global land rush: Markets, rights, and the politics of food. Stan. J. Int'l L., 49, p.101.

Swain, S., Dash, A., Mohapatra, A., Das, D., Behera, D., Nayak, B. and Mohapatra, M., 2020. Effect of mechanization on cost-economics of maize cultivation by small farmers of Gajapati District, Odisha. International Journal of Chemical Studies, 8(4), pp.3103-3107.

Eise, J.; Foster, K. *How to Feed World*; Island Press Center for Resource Economics: Washington, DC, USA, 2018; pp. 1–250. [**Google Scholar**]

European Parliament. DIRECTIVE (EU) 2015/1513 of the european parliament and of the council of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewabl. *Off. J. Eur. Union* **2015**, *L239/1*, 20–30. [**Google Scholar**]

EU. A 2030 Framework for Climate and Energy Policies. European Parliament Resolution of 5 February 2014 on a 2030 Framework for Climate and Energy Policies (2013/2135(INI)). 2014. Available online: **https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014IP0094&from=EN** (accessed on 18 January 2020).

Stelte, W.; Sanadi, A.R.; Shang, L.; Holm, J.K.; Ahrenfeldt, J.; Henriksen, U.B. Recent developments in biomass pelletization—A review. *BioResources* **2012**, *7*, 4451–4490. [**Google Scholar**]

Paiano, A.; Lagioia, G. Energy potential from residual biomass towards meeting the EU renewable energy and climate targets. The Italian case. *Energy Policy* **2016**, *91*, 161–173. [**Google Scholar**] [**CrossRef**]

Mann, M.E.; Cohen, R.D.H.; Kernan, J.A.; Nicholson, H.H.; Christensen, D.A.; Smart, M.E. The feeding value of ammoniated flax straw, wheat straw and wheat chaff for beef cattle. *Anim. Feed Sci. Technol.* **1988**, *21*, 57–66. [**Google Scholar**] [**CrossRef**]