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AI vs. traditional farming: A comparative economic analysis of sugarcane production in Pune District of Maharashtra

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Abstract

The present study targeted to compare the cost of cultivation, returns, and profitability between AI (Artificial Intelligence) and Non-AI sugarcane farmers in the Pune district of Maharashtra. With the emergence of AI technologies in agriculture such as remote sensing, automated irrigation, disease detection, and yield forecasting farmers have started exploring technology-driven methods to enhance efficiency. This study focused on analysing the differences in cost components including Cost A, Cost B and Cost C between AI and Non-AI adopters. Primary data was collected through structured interviews and surveys. The findings revealed that AI farmers incurred lower variable costs, particularly in labor, fertilizer, and plant protection due to precise input use. Although AI adoption required some initial investment, it significantly reduced operational inefficiencies. On the other hand, Non-AI farmers continued to rely on traditional practices, resulting in relatively higher costs and stagnant productivity. The study also observed that the profitability of AI farmers was comparatively higher due to better input management and increased returns. Therefore, the integration of AI in sugarcane cultivation shows promising results in improving cost-effectiveness and farm income. Promoting AI technologies through farmer training, subsidies, and infrastructure development can play a vital role in advancing sustainable and profitable sugarcane farming.

Keywords: Artificial Intelligence (AI), sugarcane cultivation, yield improvement, cost-effectiveness, net profit, Cost-A B C

Introduction

Sugarcane is a significant cash crop cultivated across India. Sugarcane is a tall perennial grass in the genus *Saccharum*, used for sugar production. The plants are usually 2-6 m tall with stout, jointed, fibrous stalks that are rich in sucrose, which accumulates in the stalk internodes. Sugarcane is native to the warm temperate to tropical regions of Southeast Asia and New Guinea and is currently mainly produced in tropical and subtropical regions. Economically, one of the most significant crops in the production of food for half of the world's population is sugarcane. Despite the nutritional value of sugarcane, excessive consumption can result in health issues like obesity, dental cavities, metabolic syndrome, and poor diet quality. In order to produce energy, sugarcane bagasse can also be ground and converted into bioethanol. Pens, mats, screens, and thatch can all be made from sugarcane reeds. The young, unexpanded flower head is consumed in certain nations.

The Government of India is giving special attention to ethanol production because it helps in many ways. Ethanol is a type of fuel made from sugarcane juice, molasses, damaged grains, or other farm products. The government started the Ethanol Blended Petrol (EBP) Programme to mix ethanol with petrol, so that the country can reduce its dependence on imported oil and also control pollution. The main goal is to achieve 20% ethanol blending with petrol by 2025. To support this, the government is giving different prices for ethanol depending on its source (like C-molasses, B-molasses, or sugarcane juice), and it is also giving loans at low interest rates to set up ethanol plants.

Sugarcane is a high-value, long-duration crop that plays a vital role in the Indian agricultural economy. It is not only a major source of sugar but also an important feedstock for ethanol production, which has gained prominence under India's biofuel blending strategy. Traditionally, sugarcane cultivation in India has been dominated by Non-AI or conventional farming practices. These include manual land preparation, traditional seed selection, fixed calendar-based irrigation and fertilizer application, and reliance on visual inspection for detecting pests and diseases. Decision-making in such systems is largely based on farmer experience, local knowledge, and seasonal weather patterns. While these methods are time-tested and accessible to smallholder farmers, they often result in low input-use efficiency, labour dependence, and yield variability due to changing climatic conditions and inconsistent crop management. In recent years, the Indian agriculture sector has witnessed the emergence of Artificial Intelligence (AI)-based technologies, which are transforming the way crops like sugarcane are cultivated. AI in agriculture refers to the use of advanced tools such as machine learning, data analytics, computer vision, drones, remote sensors, weather models, and mobile applications to collect and process large volumes of real-time data. In sugarcane farming, AI can assist in predicting the best planting time, estimating yield, detecting pests and diseases through image recognition, monitoring soil moisture via IoT sensors, and optimizing irrigation and fertilizer schedules through decision support systems. These technologies help improve precision farming, reduce input costs, and increase productivity and sustainability. For example, AI-powered drone surveillance can identify pest-infected zones early, allowing for targeted pesticide spraying rather than blanket application. In Maharashtra's sugarcane belt, particularly around Baramati and Kolhapur, the integration of AI-powered agricultural technologies has delivered transformative results. Studies show yield increases of 30-40% per acre, with farmers harvesting up to 120-150 tonnes of sugarcane, compared to 70-80 tonnes under conventional methods. The Agricultural Development Trust (ADT) in collaboration with Microsoft and Map My Crop piloted an AI platform that combines satellite imagery, IoT soil sensors, weather stations, and predictive analytics to deliver precise field-level recommendations. These systems enabled a 50% reduction in water usage, 20-30% savings in fertilizer, and 25-35% reduction in pesticide use, while increasing sucrose content by about 20%, thus boosting both yield and quality.

Objective of study

To study the economics of sugarcane crop of AI user and Non user

Hypothesis

Null Hypothesis (H0): There is no significant difference in cost and return in AI and non-AI sugarcane cultivation.

Alternate Hypothesis (H1): There is significant difference in cost and return in AI and Non-AI sugarcane cultivation.

Methodology:

The study employed a comparative survey design to assess the economics of sugarcane cultivation using cost of cultivation as the main analytical tool. Research was conducted in Pune district, Maharashtra, selected for its advanced irrigation infrastructure and adoption of AI technologies.

A multistage sampling method was used. Three talukas Baramati, Daund, and Indapur were selected purposively,

followed by random selection of 12 villages and 120 sugarcane farmers (60 AI-enabled and 60 Non-AI).

Primary data were collected through structured interviews and field observations, while secondary data were sourced from government reports, research institutions, and official statistics. The analysis compared AI and Non-AI farms in terms of costs, yields, input efficiency, and profitability, ensuring a reliable evaluation of technological interventions in sugarcane farming.

Analytical Tool

Cost Concept

The standard cost concepts i.e. Cost A, Cost B, and Cost C will be used and different marketing cost concepts were used for the present study.

Cost 'A': It includes the actual paid out costs viz; expenditure on seed, manures, fertilizers, hired human labour, bullock labour, land revenue, irrigation charges, machinery charges, interest on working capital and depreciation on farm implement and incidental charges.

Cost 'B': Cost A + Rental Value of owned land + interest on fixed capital (excluding land) @ 10%. Rental value of land = $1/6^{\text{th}}$ Gross product - Land revenue

Cost 'C': Cost B + Imputed value of family labour.

The probability of crop production cannot be justified completely unless benefit cost ratio were worked out. This is the ratio which represents returns obtained per rupee of investment. It is worked out by dividing gross return by the total cost. It is calculated at cost A, cost B and cost C as Gross Income.

$$\text{Benefit-cost ratio at cost 'A'} = \frac{\text{Gross Income}}{\text{Cost 'A'}}$$

$$\text{Benefit-cost ratio at cost 'B'} = \frac{\text{Gross Income}}{\text{Cost 'B'}}$$

$$\text{Benefit-cost ratio at cost 'C'} = \frac{\text{Gross Income}}{\text{Cost 'C'}}$$

Results and Discussion

The comparative analysis of sugarcane cultivation costs between Non-AI and AI farmers reveals notable differences in input utilization, efficiency, and cost structure. The total cost of cultivation (Cost C) for AI farmers stands at ₹3,76,020.81 per hectare, which is slightly higher than ₹3,65,107.73 incurred by Non-AI farmers. However, a deeper breakdown shows that AI farmers manage to reduce certain key operational costs through the adoption of technology, even though they may invest slightly more overall.

A significant difference is observed in human labor costs. Non-AI farmers spend ₹49,047.62 (13.43% of total cost) on hired human labor, whereas AI farmers spend ₹36,582.30 (9.73%). This reduction is a result of AI technologies automating several tasks that otherwise require manual effort. For example, male labor costs decrease from ₹32,430.56 to ₹23,730.68, and female labor from ₹16,617.06 to ₹9,550.22 under AI farming, which indicated that mechanized and AI-supported farming can reduce labour costs by up to 30%.

AI farmers, however, spend slightly more on machinery (₹15,648.96 compared to ₹11,515.87 for Non-AI), indicating a shift toward mechanized operations. Manure and fertilizer costs

also reflect improved efficiency among AI users. While Non-AI farmers spent ₹44,523.81 on manure and ₹6,544.44 on fertilizers, AI farmers reduced these costs to ₹38,134.66 and ₹5,490.07 respectively. This suggests that AI farmers are using precision application methods, such as sensor-based fertilization or data-driven nutrient management. Similarly, plant protection costs are lower for AI farmers (₹2,677.92) than for Non-AI farmers (₹3,150.79), which may be attributed to the use of AI-based pest detection and control systems.

Another important difference lies in the working capital component. Non-AI farmers have a higher working capital requirement of ₹1,50,816.57 (41.31% of cost), while AI farmers operate with a lower working capital of ₹1,27,467.51 (33.90%), suggesting more efficient cash flow and better resource planning with the use of AI. Additionally, depreciation on farm implements and interest costs are slightly lower for AI farmers,

indicating better long-term capital management. However, the rental value of land is higher for AI farmers (₹1,47,585.80 vs. ₹98,652.79 for Non-AI), possibly because AI farmers are cultivating more fertile or better-located land, or leasing technologically equipped fields.

Cost A, which includes all variable costs except land rent and capital interest, is significantly lower for AI farmers (₹1,77,107.39) than Non-AI farmers (₹2,09,708.95), demonstrating that AI reduces active cultivation costs. Cost B, which includes rental value and interest on fixed capital, is nearly the same for both groups: ₹3,55,090.90 for AI and ₹3,44,944.04 for Non-AI, indicating comparable total investment before accounting for family labor. Interestingly, family labor usage remains almost the same for both categories, suggesting cultural or economic dependence on family support remains unchanged regardless of technology use.

Table 1: Per hectare cost of cultivation of Non-AI farmers and AI Technology in sugarcane farming

Sr. No.	Particulars	Non-AI Farmer			AI Farmer		
		Qty	Value	Percentage	Qty	Value	Percentage
1	Hired Human Labour (Days)						
	a) Male	64.86	32430.56	8.88	47.46	23730.68	6.31
	b) Female	66.47	16617.06	4.55	38.20	9550.22	2.54
	Total Human Labour	131.33	49047.62	13.43	85.66	36582.30	9.73
2	Machine (Hrs)		11515.87	3.15		15648.96	4.16
3	Manure (Ton)		44523.81	12.19		38134.66	10.14
4	Seedling (Setts)		12301.59	3.37		12350.99	3.28
5	Fertilizer (Kgs)		6544.44	1.79		5490.07	1.46
	N	369.05	0	0.00	290.73	0	0.00
	P	98.41	0	0.00	56.46	0	0.00
	K	98.41	0	0.00	119.54	0	0.00
6	Micronutrients		4920.63	1.35		4940.40	1.31
7	Irrigation Charges (Rs)		16478.17	4.51		13575.06	3.61
8	Plant Protection Charges (Rs)		3150.79	0.86		2677.92	0.71
9	Incidental Charges (Rs)		1556.85	0.43		908.72	0.24
10	Repairs (Rs)		776.79	0.21		459.82	0.12
11	Working Capital		150816.57	41.31		127467.51	33.90
12	Interest on Working Capital @ 12% (Rs)		18097.99	4.96		15296.10	4.07
13	Depreciation on farm implement		40659.98	11.14		34208.83	9.10
14	Land Revenue		134.41	0.04		134.95	0.04
	Cost A		209708.95	57.44		177107.39	47.10
15	Rental value of Land		98652.79	27.02		147585.80	39.25
16	Interest on fixed capital @10% (Rs)		36582.30	10.02		30397.71	8.08
	Cost B		344944.04	94.48		355090.90	94.43
17	Family Labour (Days)			0.00			0.00
	a) Male	28.45	14226.19	3.90	30.35	15176.60	4.04
	b) Female	23.75	5937.50	1.63	23.01	5753.31	1.53
	Total Family Labour	52.20	20163.69	5.52	53.37	20929.91	5.57
	Cost C		365107.73	100.00		376020.81	100.00

Hence, The cost of production under AI technology is lower compared to Non-AI farming due to reduced labor, optimized input use, and timely operations. AI-based practices like precision irrigation, automated monitoring, and mechanized tools help in minimizing unnecessary expenses. In contrast, Non-AI farmers face higher costs due to manual practices and inefficient resource use. Thus, AI technology proves to be more cost-effective and efficient in sugarcane cultivation.

In table No. 2 presents a comparative analysis of the cost of cultivation, gross income, and net returns obtained under AI-based and Non-AI-based sugarcane farming systems. The economic comparison between AI and Non-AI sugarcane farmers shows that the adoption of AI technology significantly enhances profitability and cost-efficiency. Starting with the Cost of Cultivation, AI farmers have a slightly higher Cost C

(₹3,76,020.81/ha) compared to Non-AI farmers (₹3,65,107.73/ha). Despite this marginal increase in overall cost, AI farmers benefit from better returns due to substantial increases in gross income and net profits.

The Gross Income received by AI farmers is ₹8,86,324.50 per hectare, whereas Non-AI farmers earn ₹5,92,723.21. This substantial 49.5% increase in gross income highlights the impact of AI in improving yield, quality, and market responsiveness. These improvements are linked to AI-driven practices such as predictive yield modelling, automated irrigation, disease detection, and weather-based advisory systems. The Net Profit margin further supports this advantage. At Cost C, Non-AI farmers earn a net profit of ₹2,27,615.49, while AI farmers record a remarkable ₹5,10,303.69 more than double. Similarly, net profits at Cost A and Cost B also reflect significant gains

under AI: ₹3,83,014.27 vs ₹7,09,217.12 at Cost A and ₹2,47,779.18 vs ₹5,31,233.61 at Cost B for Non-AI and AI farmers respectively. One of the most striking indicators is the Per Ton Cost of Production, which is drastically lower under AI farming ₹1,034.95 per ton, compared to ₹2,912.36 for Non-AI farmers. This indicates higher productivity, more efficient input use, and

reduced wastage under AI-driven operations. Furthermore, the Benefit-Cost (B:C) Ratio a key measure of profitability is significantly better for AI farmers at 2.36, compared to 1.62 for Non-AI farmers. This implies that for every rupee spent, AI farmers earn ₹2.36, while Non-AI farmers earn only ₹1.62, making AI farming a far more attractive investment.

Table 2: Cost, Return and Gross Income for AI and Non AI Farming

Sr. No.	Particulars	Unit	Non-AI Farmer	AI Farmer
1	Total Cost			
	Cost "A"	Rs.	209708.95	177107.39
	Cost "B"	Rs.	344944.04	355090.90
	Cost "C"	Rs.	365107.73	376020.81
2	Gross Income	Rs	592723.21	886324.50
3	Net Profit at			
	Cost "A"	Rs	383014.27	709217.12
	Cost "B"	Rs	247779.18	531233.61
	Cost "C"	Rs	227615.49	510303.69
4	Per Ton Cost		2912.36	1034.95
5	B:C Ratio		1.62	2.36

The Benefit-Cost (B:C) ratio is significantly higher for AI farmers compared to Non-AI farmers. AI-based farming recorded a B:C ratio of 2.36, while Non-AI farming showed a lower range of 1.62. This indicates that every rupee invested by AI farmers returns over showcasing better profitability. The use

of technology, efficiency in input management, and higher yields contribute to the improved B:C ratio under AI practices. Therefore, AI farming is not only cost-effective but also economically rewarding.

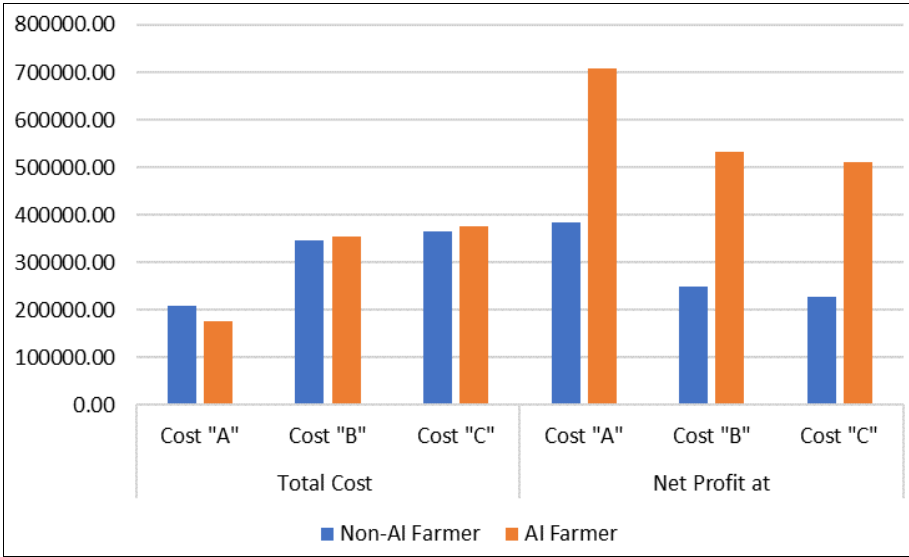


Fig 1: Cost and Profit Comparison: AI vs Non-AI Farmers

Table 3: Hypothesis Testing

	AI	Non-AI
Mean	1338350.00	497887.50
Sample var	2.29506E+11	1.64798E+11
Sample Size	60	60
Z cal	10.36759386	
Z table	1.64	1.96
Result	1% Significant	1% Significant

The calculated z-value (10.37) is much greater than both the critical values at 1% and 5% significance levels. Hence, the null hypothesis (H₀) is rejected and the alternative hypothesis (H₁) is accepted. This indicates there is highly significant difference between the Gross incomes of AI and Non-AI farmers, favouring AI-based farming practices.

Conclusion

The present study evaluated the impact of artificial intelligence (AI) technology on sugarcane farming in Pune district through a comprehensive analysis of per hectare cost of cultivation, productivity, and profitability. The results provide clear empirical evidence that AI-enabled farming practices significantly enhance economic efficiency when compared to traditional methods. AI farms demonstrated a substantial reduction in operational costs, particularly in human labour, irrigation, and incidental expenses, owing to the precision, automation, and data-driven decision-making facilitated by AI tools. Most notably, AI-integrated farms achieved a 49.5% higher yield per hectare and a significantly lower cost of production per ton, leading to markedly improved net returns and benefit-cost ratios. While AI farms showed a slightly higher total cost under

Cost B and Cost C due to capital inputs and technology investment, the overall profitability and return on investment were far superior. These findings underscore the transformative potential of AI technologies in sugarcane cultivation by improving resource use efficiency, minimizing production costs, and maximizing economic returns.

Thus, it can be concluded that the integration of AI technology offers a sustainable and economically viable pathway for modernizing sugarcane farming in Pune district. The study advocates for greater policy support, digital infrastructure, and farmer training programs to promote the wider adoption of AI in agriculture, especially among small and medium-scale farmers, to enhance productivity, profitability, and long-term sustainability.

Suggestion

1. Encourage the use of sugarcane planters, mechanical weeder, and harvesters to reduce labor dependency and costs.
2. Promote balanced use of organic (compost, green manure) and inorganic fertilizers to reduce overuse of expensive chemical inputs.
3. Adoption of drip irrigation or sprinkler systems reduces water usage and power/fuel costs for pumping.
4. Use drones, soil sensors, or AI-based tools to apply fertilizers, water, and pesticides only where needed reducing input costs.

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