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Research Paper

Cost efficiency and profitability: a relative advantage analysis of pigeonpea and sugarcane cultivation

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ABSTRACT

The present study was conducted to assess the relative advantage between two major annual crops i.e., pigeonpea (Arhar) and sugarcane in different category of farm size. Multi-stage stratified purposive cum random sampling technique were employed to collect primary information of 240 farmer households. The findings revealed that sugarcane cultivation was significantly more lucrative than pigeonpea across all farm size categories. On an overall average, sugarcane cultivation yielded a net return of ₹ 1,19,028.65/ha with a benefit cost ratio of 1:2.29, compared to pigeonpea, which yielded a net return of ₹ 32,372.60/ha and a benefit cost ratio of 1:1.65. Moreover, the production cost per quintal for sugarcane had the lowest (₹ 142.22) than pigeonpea (₹ 4,783.69). Sugarcane relative advantage as a more economically sustainable option in North Eastern Plain Zone. Policymakers and agencies can use the study's insightful findings to help farmers grow more profitable crops.

***Key words*:** CACP, Costs and Returns, Pigeonpea, Profitability, Sugarcane

INTRODUCTION

Agriculture plays an important role in the economy of Uttar Pradesh, generating income, providing employment opportunities, and promoting rural growth and development. The North Eastern Plain Zone of Uttar Pradesh has diverse agro-climatic conditions supporting the cultivation of a variety of crops such as rice, wheat, maize, sugarcane, arhar, urd, moong, mustard, and vegetables like potato, cauliflower, brinjal, and tomato (Mishra *et al*. 2025). Among these, pigeonpea, which is a major pulse crop, and sugarcane, a vital commercial crop, are both widely cultivated by farmers due to their adaptability to local conditions and market demand. Pigeonpea enhances soil fertility through nitrogen fixation and income generation, especially for small and marginal farmers. Sugarcane contributes significantly to the rural economy by providing raw material for sugar and related industries, along with employment opportunities across the value chain (Cardoso *et al*. 2018).

Pigeonpea (*Cajanus cajan* L.) is also known as red gram, Arhar is among the most important pulse cultivated in India (Kumari *et al*. 2015). It is the major *kharif* crop rich in iron, calcium, iodine, essential amino acids like lysine, threonine, cystine and arginine (Joshi *et al*. 2001). India ranks 1st in both the area with 46 lakh hectares and production with 38.11 lakh tons (Bodakhe *et al*. 2023). More than 90% of total pigeonpea production is concentrated in 8 states, namely Maharashtra, Karnataka, Madhya Pradesh, Uttar Pradesh, Gujarat, Jharkhand, Telangana, and Andhra Pradesh (Pal *et al*. 2016). Uttar Pradesh ranks 3rd in both area and production with 2.94 lakh hectares and 3.13 lakh tons, respectively, in 2022-23. It is not only vital for domestic consumption but also exported to the USA, UAE, Nepal, Canada, Qatar, United Kingdom, Singapore, and Australia (Emefiene *et al*. 2014).

Sugarcane (*Saccharum officinarum L.)* is a major commercial crop in India. Sugarcane is a natural, renewable resource for agriculture because it not only produces sugar but also biofuel, fibre, fertilizer, and numerous other environmentally friendly by-products (Amorim *et al*. 2021). India is one of the world's leading producers of sugarcane with a total cultivated area of approximately 5.45 million hectares in 2023-24 and production reaching about 453.1 mt. The crop is intensively cultivated in three states: Uttar Pradesh, Maharashtra, and Karnataka, which together account for nearly

80% of the country's total sugarcane output (Kant *et al*. 2015). In 2023-24, Uttar Pradesh produces 215.8-million-ton sugarcane, making it the leading sugarcane-producing state. India exports sugar to several countries, including Indonesia, Bangladesh, Sri Lanka, Somalia, and Sudan, further enhancing the crop's economic value. The byproduct from sugarcane as used from various purposes, bagasse, is used as biofuel, for electricity generation, raw material for paper generation, and board manufacturing. Molasses is converted into alcohol and used as animal feeds (Bajay *et al*. 2011). These by-products of sugarcane provide additional income for the farmers and increase the crop profitability.

Pigeonpea and sugarcane are cultivated under similar agro-ecological conditions; the choice between pigeonpea and sugarcane poses a dilemma for farmers. Factors such as market price volatility, production costs, labour requirements, and profitability influence farmers' crop selection. While sugarcane is traditionally seen as a high-revenue crop, it is also resource- and labour-intensive, whereas pigeonpea requires comparatively lower inputs but often yields lower monetary returns (Junkraweekoon *et al*. 2025). An in-depth comparative analysis of cost-benefit and profitability between pigeonpea and sugarcane can provide valuable insights for farmers, policymakers, and extension agencies (Abnave *et al*. 2021). The study aims to identify the profitable and cost-efficient crop under prevailing production and market conditions, thereby assisting in decision-making and policy formulation for the region's farming community. The present study has been carried out with two major objectives, including (i) to calculate the cost of cultivation and profit measures of pigeonpea and sugarcane production in the North Eastern Plain Zone of Uttar Pradesh, and (ii) to assess the relative economic advantage of pigeonpea vis-à-vis sugarcane cultivation in the North Eastern Plain Zone of Uttar Pradesh.

MATERIAL AND METHODS

The study was conducted in *Siddharth Nagar* and *Bahraich* districts, located in the North Eastern region of Uttar Pradesh. Siddharthnagar district lies between 26°52′ and 27°28′ north latitude and 82°45′ to 83°10′ east longitude (Government of Uttar Pradesh, 2023). It is bordered by Nepal to the north, Maharajganj district to the east, Basti district to the south, and Gonda district to the west. The district is named after Lord Buddha, who spent a significant part of his early life in this region. The district headquarters, Naugarh (Siddharthnagar city), is located approximately 115 km north of Gorakhpur (District Census Handbook 2011). Bahraich district is located between 27°28′ and 28°42′ north latitude and 81°3′ to 81°48′ east longitude. It shares an international boundary with Nepal to the north and is bounded by Lakhimpur Kheri in the west, Sitapur in the southwest, Barabanki in the south, Gonda in the southeast, and Shravasti in the east. The district headquarters, Bahraich city, is situated about 125km northwest of Lucknow, the state capital. The district forms part of the Terai region and features a mix of plain and forested terrain, making it agriculturally significant (District Census Handbook, 2011). Keeping in mind the objectives of the study, multi stage stratified purposive cum random sampling technique was used.

The study employed a multi-stage stratified purposive cum random sampling technique across *Siddharth Nagar* and *Bahraich* districts. In the first stage, five developmental blocks were randomly selected from each district. In the second stage, five villages were randomly chosen from each selected block, totalling 50 villages. In the final stage, 240 farmer households (120 from each district) were selected using proportionate allocation based on landholding size, such that 135 marginal (56.25%), 80 small (33.33%), and 25 medium (10.41%) farmers. A pre-tested structured interview schedule was used for data collection, focusing on farmers cultivating Pigeonpea and sugarcane during 2022-23.

Modelling

The cost of production and returns for the farmer household were calculated on a per-hectare basis for the pigeonpea and sugarcane crops in each category in order to achieve this goal. The gross return from each chosen crop was calculated to estimate the crop's return (CACP Department of Agriculture and Cooperation, 2011–12).

$GR_j = Y_j P_j$

$NR_j = GR_j - COC_j$

Where,

GR_j =Gross return from J^{th} crop; Y_j= Yield of j^{th} crop in quintal

P_j = Price of j^{th} crop per quintal; NR_j = Net Return from j^{th} crop

COC_j = Cost of Cultivation of j_{th} crop

j = selected crop (1, 2, 3 and 4)

- Farm investment income=Net farm income+

interest on fixed capital+rental value of owned land.

- Family labour income= Gross income–Cost B_2.
- Farm business income=Gross income –Cost A_1 or Cost A_2.
- Benefit-cost ratio = Cost C / Gross Income

The expenditure incurred on purchasing inputs like seeds, fertilizers, plant protection chemicals, etc., was directly observed, but expenditure incurred on fixed assets (like land, machinery, implements, etc.) and imputed value of family labour (FL) were not directly observed. So cost concepts (Costs A, B, C) as given by CACP were used to give a realistic picture of the total cost incurred on the cultivation of various crops.

Cost A_1: All variable cost excluding family labour costs and including land revenue, depreciation and Interest on working capital.

Cost A_2: Cost A_1+rent paid for leased land

Cost B_1: Cost A_2+interest on value of owned fixed capital assets(including land)

Cost B_2: Cost B_1+rental value of owned land.

Cost C_1: Cost B_1+imputed value of family labour

Cost C_2: Cost B_2+imputed value of family labour

Cost C_3: Cost C_2+10%of C_2 (managerial cost)

Operational costs were estimated using prevailing rates in the study area. Wages for hired labour, including cash and kind payments, were converted at market rates, while family labour was imputed similarly. Machinery costs were based on hiring charges for non-owners and fuel, repair, and maintenance for owners. Material costs (seeds, manure, fertilizers, chemicals, and irrigation) were calculated per hectare at prevailing prices. Owned seeds were valued at market rates. Additional costs included interest on fixed assets, interest on working capital (4% per annum), and the rental value of land, all assessed using prevailing rates and asset utilization.

RESULTS AND DISCUSSION

Cost of cultivation on pigeonpea

To assess the economic analysis of pigeonpea (arhar) cultivation and its impact on farmers' profitability, the cost of cultivation was analyzed. Table 1 depicts the per-hectare costs of different inputs used in pigeonpea production. Human labour constituted the largest share of the variable cost, with an overall average expenditure of ₹13754.56 per hectare, accounting for 28.12% of the total cost. Family labour costs were higher for marginal farmers (₹9832.56), while hired labour costs increased with farm size, being highest for medium farms (₹13862.56). Machinery charges accounted for 10.22% (₹4997.74), followed by irrigation (7.48%), manure and fertilizers (6.06%), Seed (5.26%), and plant protection (1.17%), respectively total cost of cultivation.

The cost incurred for Interest on working capital, rental value of land, interest on fixed capital, and 10% managerial cost, with sub-total accounted for 0.74%, 30.67%, 1.18% and 9.09% of total cost, respectively. The maximum share among these costs was the rental value of owned land, which was ₹15000 of the total cost of cultivation per hectare.

However, per hectare Cost A_1 on marginal, small, and medium farms were found to be ₹16528.05, ₹26645.24, and ₹30886.62, respectively. The analysis revealed that the prevailing wage rate of ₹210 per man-day exceeded the statutory minimum wage rate of ₹205 per man-day. As a result, the Cost C_2 and Cost C_2* were identical across all farm size groups in the study area are represented in Table 2. The per-hectare Cost C_3, representing the total cost of pigeonpea cultivation inclusive of the farmer's managerial expenses, was highest for medium-sized farms, amounting to ₹53603.66. This expenditure was 1.16 times greater than the cost incurred by marginal farmers, which stood at ₹46121.33. On average, the per-hectare cost of pigeonpea cultivation across all farm categories in the study area was calculated to be ₹48909.40.

Income measures of pigeonpea cultivation

Income from pigeonpea production was calculated and is given in Table 3. The per-hectare gross income was highest for medium farms (₹104400.00), followed by small farms (₹98160.00) and marginal farms (₹65100.00), with an overall average of ₹81282.00 per hectare. The Benefit-Cost Ratio (BCR) revealed a profitable trend, with medium farms achieving the highest BCR of 1:1.95, followed by small farms (1:1.90) and marginal farms (1:1.41). The overall BCR for sugarcane cultivation was 1:1.65, indicating that for every ₹1.00 invested, farmers earned ₹1.65.

Table 1. Per hectare costs of different inputs used in pigeonpea production (₹)

S. No.	Particulars	Size group of farms			
		Marginal (135)	Small (80)	Medium (25)	Overall average
1	Human Labour	12306.23 (26.68)	15161.13 (29.40)	16121.45 (30.08)	13754.56 (28.12)
a.	Family Labour	9832.56 (21.32)	4648.80 (9.01)	2258.89 (4.21)	7124.69 (14.57)
b.	Hired Labour	2473.67 (5.36)	10512.33 (20.39)	13862.56 (25.86)	6629.86 (13.56)
2	Machinery Charges	4687.55 (10.16)	5248.72 (10.18)	5648.54 (10.54)	4997.74 (10.22)
3	Seed	2439.61 (5.29)	2681.45 (5.20)	2842.46 (5.30)	2571.92 (5.26)
4	Manure and fertilizer	2645.32 (5.74)	3279.32 (6.36)	3482.11 (6.50)	2965.69 (6.06)
5	Irrigation	3456.73 (7.49)	3864.56 (7.49)	3968.34 (7.40)	3659.59 (7.48)
6	Plant Protection/Intercultural	478.41 (1.04)	680.53 (1.32)	684.59 (1.28)	573.22 (1.17)
7	Total operational cost	26013.85 (56.40)	30915.71 (59.95)	32747.49 (61.09)	28522.72 (58.32)
8	Interest on working capital	346.76 (0.75)	378.33 (0.73)	398.02 (0.74)	363.87 (0.74)
9	Rental value of land	15000.00 (32.52)	15000.00 (29.09)	15000.00 (27.98)	15000.00 (30.67)
10	Interest on fixed capital	567.87 (1.23)	586.80 (1.14)	585.09 (1.09)	576.50 (1.18)
11	Sub total	41928.48 (90.91)	46880.84 (90.91)	48730.60 (90.91)	44463.09 (90.91)
12	Managerial Cost@10% of sub-total	4192.85 (9.09)	4688.08 (9.09)	4873.06 (9.09)	4446.31 (9.09)
Grand total		46121.33 (100.00)	51568.92 (100.00)	53603.66 (100.00)	48909.40 (100.00)

Note: Figures in parentheses indicates the percentage of total cost

The average net return over Cost C_3 was ₹32372.60 per hectare, with medium farms achieving the highest net return of ₹50796.34 per hectare. Farm business income, representing net return over Cost A_1, was ₹59520.09 per hectare on average, with medium farms again leading at ₹73513.38. Family labor income (net return over Cost B_2) and farm investment income were ₹43943.60 and ₹52395.40 per hectare, respectively.

The cost of production per quintal varied with farm size, averaging ₹4783.69 per quintal across all farms. Medium farms had a slightly lower cost of production (₹4107.56/q) compared to small farms (₹4202.85/qtl.), while marginal farms incurred the highest cost (₹5313.352/q).

The yield per hectare increased with farm size, being highest on medium farms (13.05 qtl./ha), followed by small farms (12.27 q/ha) and marginal farms (8.68 qtl./ha), with an overall average yield of 10.45 qtl./ha. Pigeonpea cultivation in the study area proved to be profitable across all farm sizes, with medium farms performing the best in terms of profitability measures, yield, and net returns.

Cost of cultivation on sugarcane

To assess the economic analysis of sugarcane cultivation and its impact on farmers' profitability, the cost of cultivation was analyzed. Table 4 depicts the per-hectare costs of different inputs used in sugarcane production. Human labour constituted the largest share of the variable cost, with an overall average expenditure of ₹28961.38 per hectare, accounting for 31.41% of the total cost. Family labour costs were higher for marginal farmers (₹21636.01), while hired labour costs increased with farm size, being highest for medium farms (₹14834.45). Seed/ Planting Materials accounted for 16.78% (₹15467.98/ ha), followed by manure and fertilizers (8.22%), machinery charges (7.16%), irrigation (1.86%), and plant protection (1.85%), respectively total cost of cultivation.

Table 2. Concept wise cost of cultivation of pigeonpea crop (₹/ha)

Cost of Cultivation	Size group of farms			
	Marginal (135)	Small (80)	Medium (25)	Overall average
Cost A_1/A_2	16528.05	26645.24	30886.62	21761.91
Cost B_1	17095.92	27232.04	31471.71	22338.40
Cost B_2	32095.92	42232.04	46471.71	37338.40
Cost C_1	26928.48	31880.84	33730.60	29463.09
Cost C_2	41928.48	46880.84	48730.60	44463.09
Cost C_2^*	41928.48	46880.84	48730.60	44463.09
Cost C_3	46121.33	51568.92	53603.66	48909.40

Table 3. Cost of production and returns from pigeonpea crop

Particulars	Marginal (135)	Small (80)	Medium (25)	Overall Average
Yield (q/ha.)	8.68	12.27	13.05	10.45
Gross Income (₹/ha)	65100	98160	104400	81282.00
Net Return (₹/q) over Cost C_3	18978.67	46591.08	50796.34	32372.60
Farm Business Income (Net Return over Cost A_1)	48571.95	71514.76	73513.38	59520.09
Family Labour Income (Net Return over Cost B_2)	33004.08	55927.96	57928.29	43943.60
Farm investment income (₹/ha)	38739.39	66865.96	71254.49	52395.40
Benefit-Cost Ratio	1:1.41	1:1.90	1:1.95	1:1.65
Cost of production (₹/q)	5313.52	4202.85	4107.56	4783.69

The cost incurred for Interest on working capital, rental value of land, interest on fixed capital, and 10% managerial cost with sub-total accounted for 3.36%, 19.52%, 0.74% and 9.09 percent of total cost, respectively. The maximum share among these costs was the rental value of owned land, which was ₹18000 of the total cost of cultivation per hectare.

However, per hectare Cost A_1 on marginal, small, and medium farms were found to be ₹41692.74, ₹47467.96, and ₹55038.59, respectively. The analysis revealed that the prevailing wage rate of ₹210 per man-day exceeded the statutory minimum wage rate of ₹205 per man-day. As a result, the Cost C_2 and Cost C_2* were identical across all farm size groups in the study area are shown in Table 5. The per-hectare Cost C_3, representing the total cost of sugarcane cultivation inclusive of the farmer's managerial expenses, was highest for medium-sized farms, amounting to ₹98527.06. This expenditure was 1.23 times greater than the cost incurred by marginal farmers, which stood at ₹90204.74. On average, the per-hectare cost of sugarcane cultivation across all farm categories in the study area was calculated to be ₹92198.65.

Income measures of sugarcane cultivation

Income from sugarcane production was calculated and is given in Table 6. The per-hectare gross income was highest for medium farms (₹251402.40), followed by small farms (₹233957.50) and marginal farms (₹187386.00), with an overall average of ₹211227.29 per hectare. The Benefit-Cost Ratio (BCR) revealed a profitable trend, with medium farms achieving the highest BCR of 1:2.55, followed by small farms (1:2.51) and marginal farms (1:2.08). The overall BCR for sugarcane cultivation was 1:2.29, indicating that for every ₹1.00 invested, farmers earned ₹2.29.

The average net return over Cost C_3 was ₹119028.65 per hectare. Medium farms had the highest net return of ₹152875.35 per hectare. Farm business revenue (net return above Cost A_1) averaged ₹165924.66 per hectare, with medium farms topping at ₹196363.81. Farm investment income was ₹146089.66 per hectare, whereas family labour income (net return above Cost B_2) was ₹147245.35.

The cost of production per quintal varied with farm size, averaging ₹142.22/q across all farms. Medium farms had a slightly lower cost of production (₹141.09/q) compared to small farms (₹139.22/q), while marginal farms incurred the highest cost (₹144.42/q).

The yield per hectare increased with farm size, being highest on medium farms (698.34 q/ha), followed by small farms (668.45 q/ha) and marginal farms (624.62 q/ha), with an overall average yield of 648.69 q/ha. Sugarcane cultivation in the study area proved to be profitable across all farm sizes, with medium farms performing the best in terms of profitability measures, yield, and net returns.

As shown in Figure 1, the net returns from sugarcane cultivation are consistently higher than those from pigeonpea for marginal, small, and

Table 4. Per hectare costs of different inputs used in Sugarcane production (₹)

S. No.	Particulars	Size group of farms			
		Marginal (135)	Small (80)	Medium (25)	Overall average
1	Human Labour	29178.46 (32.35)	28026.70 (30.12)	30678.35 (31.14)	28961.38 (31.41)
a.	Family Labour	21636.01 (23.99)	18452.04 (19.83)	15843.90 (16.08)	19835.01 (21.51)
b.	Hired Labour	7542.45 (8.36)	9574.66 (10.29)	14834.45 (15.06)	9126.37 (9.90)
2	Machinery Charges	6378.34 (7.07)	6856.32 (7.37)	6862.33 (6.96)	6602.12 (7.16)
3	Seed	15236.05 (16.89)	15645.21 (16.81)	15984.44 (16.22)	15467.98 (16.78)
4	Manure and fertilizer	6498.65 (7.20)	8532.11 (9.17)	9645.77 (9.79)	7582.17 (8.22)
5	Irrigation	1643.66 (1.82)	1762.40 (1.89)	1897.32 (1.93)	1715.37 (1.86)
6	Plant Protection/Inter-culture	1526.92 (1.69)	1829.43 (1.97)	2165.73 (2.20)	1708.73 (1.85)
7	Total working capital	60462.08 (67.03)	62652.17 (67.32)	67233.94 (68.24)	62037.75 (67.29)
8	Interest on working capital	2866.67 (3.18)	3267.83 (3.51)	3648.55 (3.70)	3099.88 (3.36)
9	Rental value of land	18000.00 (19.95)	18000.00 (19.34)	18000.00 (18.27)	18000.00 (19.52)
10	Interest on fixed capital	675.56 (0.75)	682.23 (0.73)	687.56 (0.70)	679.32 (0.74)
11	Sub total	82004.31 (90.91)	84602.23 (90.91)	89570.05 (90.91)	83816.95 (90.91)
12	Managerial Cost@10% of sub-total	8200.43 (9.09)	8460.22 (9.09)	8957.01 (9.09)	8381.70 (9.09)
	Grand total	90204.74 (100.00)	93062.45 (100.00)	98527.06 (100.00)	92198.65 (100.00)

Note: Figures in parentheses indicates the percentage of total cost

medium farmers. The present study provides clear evidence of the relative economic performance of pigeonpea and sugarcane under the agro-economic conditions of the North Eastern Plain Zone of Uttar Pradesh. The results indicate that sugarcane offers a distinct short-term economic advantage over pigeonpea across all farm size categories, primarily due to its higher yield per hectare, assured market linkages with sugar mills, and relatively stable pricing structure. These features significantly reduce market uncertainty and make sugarcane an attractive option for farmers aiming to maximize cash income.

From a crop-choice perspective, the substantially higher net returns and benefit–cost ratios of sugarcane suggest that it is better suited for farmers with adequate access to irrigation, labour, and capital, particularly small and medium farmers who can absorb higher initial investments. Similar findings have been reported from other regions of Uttar Pradesh and India, where sugarcane cultivation has been associated with greater income stability and higher profitability owing to strong institutional support and well-developed value chains (Kant *et al.* 2015, Srivastava *et al.* 2024).

However, the findings also emphasize that economic superiority alone should not be the sole criterion for crop selection in the North Eastern Plain Zone. Pigeonpea, despite yielding lower monetary returns, requires lower cash inputs, less irrigation, and fewer purchased inputs, making it a comparatively less risky crop for marginal farmers with limited resources. Evidence from pulse-growing regions of Maharashtra and Bihar similarly indicates that pigeonpea remains economically relevant for resource-poor farmers due to its lower cost structure and suitability under rainfed conditions (Kumari *et al.* 2015, Bodakhe *et al.* 2023).

An important implication for the region is that pigeonpea contributes to cropping system sustainability through biological nitrogen fixation, which enhances soil fertility and may reduce fertilizer requirements for subsequent crops. Although this benefit was not monetized in the present analysis, excluding such long-term ecological advantages may underestimate the overall value of pigeonpea in diversified farming systems. This observation is consistent with the findings of Pal *et al.* (2016), who highlighted the role of pulses in maintaining soil health and improving system productivity.

The comparative analysis further indicates that farm size plays a crucial role in determining

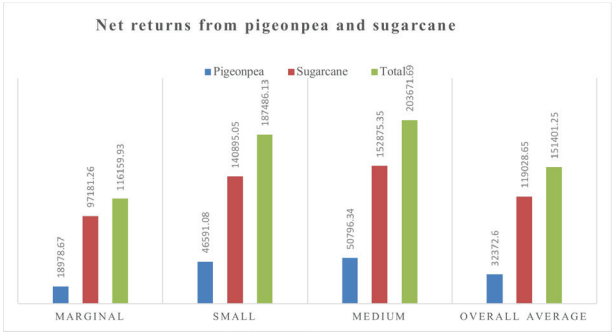

Fig. 1. Net return of pigeonpea and sugarcane in North Eastern plain zone of Uttar Pradesh

relative advantage. Medium farmers achieved higher yields and lower unit costs for both crops, reflecting economies of scale, better access to inputs, and improved management practices. In contrast, marginal farmers—particularly in pigeonpea cultivation—faced higher costs per unit of output, underscoring the need for productivity-enhancing interventions and institutional support.

Overall, the discussion suggests that while sugarcane is the preferred crop for maximizing short-term profitability in the North Eastern Plain Zone of Uttar Pradesh, pigeonpea continues to play an important role in risk diversification, soil health improvement, and livelihood security, especially for small and marginal farmers. Therefore, crop-choice decisions in the region should be guided by resource availability, risk-bearing capacity, and long-term sustainability considerations rather than profitability alone.

Limitations of the study

Despite providing valuable insights into the comparative cost efficiency and profitability of pigeonpea and sugarcane cultivation, the study has certain limitations. First, the analysis primarily focuses on economic indicators such as costs, returns, and profitability measures, without incorporating environmental and ecological benefits associated with pigeonpea cultivation. Pigeonpea is a leguminous crop known for its biological nitrogen fixation, improvement of soil fertility, and contribution to sustainable cropping systems. These long-term soil health benefits were not monetized or incorporated into the profitability framework. Second, the study does not account for water use efficiency and environmental externalities, which are particularly relevant for sugarcane, a water-intensive crop. Ignoring such factors may overstate the relative economic advantage of sugarcane

in regions facing groundwater stress. Third, the analysis is based on single-year primary data (2022–23), and hence does not capture year-to-year variability in yields, prices, and climatic conditions. Inclusion of multi-year data could provide a more robust assessment of profitability and risk.

These limitations suggest that future studies should adopt an integrated framework combining economic, environmental, and sustainability indicators to provide a more holistic evaluation of crop choice decisions.

Policy implications and recommendations

Although sugarcane cultivation was found to be more profitable across all farm size categories, excessive dependence on a single commercial crop may increase vulnerability to market and environmental risks. Therefore, a balanced crop policy is essential for sustainable agricultural development in the North Eastern Plain Zone of Uttar Pradesh.

Given the lower profitability of pigeonpea despite its agronomic and nutritional importance, targeted policy interventions are necessary to enhance its economic viability. These may include:

- Price support mechanisms such as effective implementation of Minimum Support Price (MSP) and assured procurement for pigeonpea;
- Input subsidies for quality seeds, bio-fertilizers, and plant protection measures to reduce the cost of cultivation;
- Productivity enhancement through extension services, promotion of improved varieties, and dissemination of best agronomic practices;
- Incentives for pulse cultivation under crop diversification and soil health improvement programs, recognizing pigeonpea's role in nitrogen fixation and sustainability.

At the same time, while promoting sugarcane cultivation for income enhancement, policymakers should encourage efficient water management practices, mechanization, and diversification strategies to mitigate environmental risks associated with continuous sugarcane monoculture.

A region-specific, integrated policy approach that combines economic profitability with ecological sustainability would enable farmers to make informed crop choices while ensuring long-term agricultural resilience.

Table 5. Concept wise cost of cultivation of sugarcane crop (₹/ha)

Cost of Cultivation	Size group of farms			
	Marginal (135)	Small (80)	Medium (25)	Overall average
Cost A_1/A_2	41692.74	47467.96	55038.59	45302.63
Cost B_1	42368.30	48150.19	55726.15	45981.94
Cost B_2	60368.30	66150.19	73726.15	63981.94
Cost C_1	64004.31	66602.23	71570.05	65816.95
Cost C_2	82004.31	84602.23	89570.05	83816.95
Cost C_2^*	82004.31	84602.23	89570.05	83816.95
Cost C_3	90204.74	93062.45	98527.06	92198.65

Table 6. Cost of production and returns from sugarcane crop

Particulars	Marginal (135)	Small (80)	Medium (25)	Overall Average
Yield (q/ha.)	624.62	668.45	698.34	648.69
Gross Income (₹/ha)	187386.00	233957.50	251402.40	211227.29
Net Return (₹/q) over Cost C_3	97181.26	140895.05	152875.35	119028.65
Farm Business Income (Net Return over Cost A_1)	145693.26	186489.54	196363.81	165924.66
Family Labour Income (Net Return over Cost B_2)	127017.70	167807.31	177676.25	147245.35
Farm investment income (₹/ha)	124057.25	168037.50	180519.91	146089.66
Benefit-Cost Ratio	1:2.08	1:2.51	1:2.55	1:2.29
Cost of production (₹/q)	144.42	139.22	141.09	142.22

CONCLUSION

From the above discussion highlighted that, pigeonpea and sugarcane being annual in nature and grown under similar agro-climatic conditions, in which sugarcane provided significantly higher net returns, benefit-cost ratios, and yields per hectare across all farm size groups. Whereas, pigeonpea cultivation was characterized by higher variability in cost of production per quintal, lower gross and net returns, and limited economies of scale, especially for marginal farmers. The average net return from sugarcane (₹1,19,028.65/ha) was over three times higher than pigeonpea (₹32,372.60/ha), with the production cost per quintal being significantly lower for sugarcane (₹142.22) as compared to pigeonpea (₹4,783.69). These findings indicate that sugarcane is a more sustainable and economically viable cropping option, particularly for farmers aiming to maximize profitability and optimize input use in the North Eastern Plain Zone of Uttar Pradesh. The study recommends that policy support, extension services, and market access initiatives should prioritize sugarcane to enhance farm-level income and improve livelihood security in the region.

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