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Assessment of Economic Viability and Production Dynamics of Chilli Cultivation in Guntur District, Andhra Pradesh

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ABSTRACT

This study evaluates the economic viability and production dynamics of chilli (*Capsicum annuum* L.) cultivation in Guntur district, Andhra Pradesh, with emphasis on growth trends, cost–return structures, and risk factors influencing farmer profitability. Two mandals Medikonduru and Vatticherukuru, were purposively selected, and 120 farm households were sampled using probability-proportional-to-size (PPS) methodology. The results revealed robust growth in chilli cultivation, with compound growth rates (CGRs) of 11.5% (area), 12.8% (production), and 8.2% (productivity), subject to a structural break around 2010–11. The corrected cost analysis showed an average C3 cost of ₹125,916 per acre, yielding a gross return of ₹168,000, net return of ₹42,084, BCR of 1.33, and a cost of production of ₹157.4/kg. Scenario analysis confirmed strong sensitivity to price and yield fluctuations, with profitability margins narrowing under adverse conditions. The Monte Carlo simulation indicated a mean NPV of ₹41,894, moderate variability of ₹16,963, and low downside risk 0.32%, underscoring price volatility as the dominant determinant of profitability. By integrating growth trend analysis, corrected cost-return estimates, and stochastic risk modelling, this study provides a comprehensive and empirically grounded assessment of chilli farming economics in India's leading production hub. The findings highlight the importance of price stabilization, crop insurance, and efficient market linkages to enhance farm resilience and profitability.

Key words: cost, zivot-andrews, compound growth rate, profit, monte carlo sensitivity

INTRODUCTION

Chilli (*Capsicum annuum* L.) is referred as "hot pepper". It is also called the "wonder spice" and is widely grown in many countries as a vegetable and a substantial crop (Rao & Rao, 2014). There are about 400 different varieties of chillies in the world (DMI, 2009). The top ten nations, including Ethiopia, Benin, Burma, Ghana, India, Bangladesh, Thailand, Ethiopia, and Pakistan, are producing chillies worldwide. Chillies are considered the most valued crop and major agricultural commodities in India. Indian chillies are a significant export good exported to various nations, generating foreign exchange profits. In India, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, Maharashtra, and Karnataka states are top chilli producers. The total area under chilli is 258,204 hectares (2022–2023), the main contributing districts are Palanadu, Ananthapuram, and Guntur districts. In 2022–23, chillies yielded 1,458,787 thousand metric tonnes per hectare, and the productivity of chillies was 5650 kg/ha (NHB, 2023). The increasing price of fertilizers, labour and pesticides led to a vast increase in the cost of chilli cultivation (Sharma & Singh, 2015). The availability of stored goods, different varieties of chillies, irregular rainfall, and national production levels all impact the chilli market. At this juncture, the study aims to analyze the economic analysis of chilli in the Guntur district of Andhra Pradesh with the following specific objectives: (i) To analyze the area, production, and productivity of chilli in the study area. (ii) To analyze the cost and returns of the chilli in the study area. Hypotheses: H1: Rising input costs significantly reduce net returns from chilli cultivation. H2: Price fluctuations significantly affect the profitability of chilli farmers.

LITERATURE REVIEW

Srikala et al. (2016) conducted an economic analysis of chilli cultivation in Guntur district, assessing the cost of cultivation and price spread. Their findings emphasized the importance of efficient resource utilization and market strategies to enhance profitability for chilli farmers. Sudeepthi et al. (2025) analyzed the agricultural and price trends of GI-tagged Guntur Sannam chilli over a 30-year period. The study observed significant increases in cultivation area and production post-GI registration, attributed to technological advancements and better land management. However, productivity growth was slower, potentially due to various limitations. The use of ARCH-GARCH and VAR models highlighted the importance of historical price trends in managing price volatility. Kumar (2020) conducted an economic analysis of red chilli production, revealing that both gross and net returns increased with farm size. The average cost of cultivation per hectare ranged from Rs. 2,86,047.59 for marginal farmers to Rs. 3,18,647.42 for large farmers. Net returns followed a similar trend, emphasizing economies of scale in chilli cultivation. The study also noted challenges such as high labour costs and price fluctuations. According to Bonigala (2024), the cost of cultivation of Guntur Sannam chilli and Teja variety chilli was Rs. 314,318 and Rs. 303,892 per acre, with realised returns of 1.85 and 1.64 per rupee of expenditure, respectively, indicating that Guntur Sannam chilli cultivation was more profitable than Teja chilli cultivation.

METHODOLOGY

Guntur district was purposively chosen from among Andhra Pradesh's 26 districts since it is one of the largest in terms of chilli area, production, and yield, with 25,251 ha, 113,359 tonnes and 4489 kgs/hectare, respectively. Because of the district's strong demand, the area under cultivation has steadily increased. In terms of Mandal selection, Medikonduru and Vatticherukuru Mandal were purposefully chosen since they had the highest area and chilli output in the Guntur district. From the selected mandals, sampling was conducted with 120 sample farmers using Probability-proportional-to-size, with chilli acreage as the size measure. The sampling frame comprised 2,530 chilli-growing households obtained from the Department of Agriculture, Guntur (2023). Villages served as the primary sampling units (PSUs) and households as the secondary sampling units (SSUs). The sample size was derived using standard formulae for proportion estimates at a 95% confidence level and a design effect of 1.2, ensuring representativeness. Primary data were collected through personal interviews with farmers using a pre-tested questionnaire.

Tools of Analysis: Structural breaks in time series data (2002–2022) were tested using Zivot-Andrew's break tests, and CGRs were estimated separately for the sub-periods. All monetary values were adjusted to real 2023 rupees using the Consumer Price Index for Industrial Workers (CPI-IW) deflator. Carlo Sensitivity analysis (1000 iterations) was applied to price and fertilizer cost variability to derive the Net Present Value (NPV) distribution.

Sampling Design

The required sample size (n) was derived using the standard formula for estimating proportions at a given precision:

$$n = (Z^2 \times p(1 - p))/e^2 \times DEFF$$

where Z is the standard normal variate at 95% confidence (=1.96), P is the anticipated proportion of households engaged in chilli farming (set conservatively at 0.5 to maximize sample size), e is the desired precision (0.09), and DEFF is the design effect (1.2 to account for PPS sampling).
This yielded a sample size close to 120 households, which was then proportionately allocated across the selected villages. Respondents were chosen randomly from village lists. This approach ensured both representativeness and efficiency, enhancing the external validity of the results.

Growth Rate Analysis

To analyse the trend in area, production and productivity of chilli in the Guntur district of Andhra Pradesh, the compound growth rate analysis was computed using the exponential growth model.

$$Yt = abt$$

where,
Yt = Total production of chilli in the Year 't'
a = Constant term
b =Parameter to be estimated
t = Time period in years
By taking natural logarithms on both sides of the equation, the following form was obtained.

$$ln\, y = ln\, a + t\, lnb$$

The CGR is given as

$$CGR = lnYt = \alpha + \beta t + \epsilon t,\ CGR = (e\beta - 1) \times 100$$

Zivot-Andrews (ZA) Break Test

The Zivot-Andrews (ZA) break test is a statistical method used to detect a single structural break in a time series at an unknown point. In this study, the Zivot-Andrews test can be used to check whether there was a significant change (break) in the trend, for instance, due to policy shifts, technological interventions, or major climate events.

$$\Delta y_t = \mu + \theta DU_t + \beta t + \gamma DT_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i + \Delta y_{t-1} + \epsilon_t$$

DUt: Dummy for intercept break (equals 1 if it t > TB, else 0)
DTt: Dummy for trend break (equals t-TB if it t > TB, else 0)
TBTBTB: unknown break date (endogenously determined)
Additionally, a cost-return analysis, as outlined was employed to examine the economic aspects of chilli cultivation.

Cost Return Analysis: The total costs were divided into two broad categories: A. Variable costs, B. Fixed costs

A. Variable Costs: Variable costs contain planting material cost, manures and fertilizers, soil amendments, wages to human and labour, plant protection chemicals, charges of irrigation, expenses on other miscellaneous and interest on working capital.

B. Fixed Costs: Fixed costs comprise to taxes on land, depreciation on farm implements and machinery, rental value of own land and interest on fixed capital and other capital structures.

Cost A1

It includes all actual expenses in cash and kind incurred during production by the farmer.

i. Value of hired human labour
ii. Value of machine labour
iii. Value of tissue culture plants
iv. Value of manure
v. Value of fertilizers and plant protection chemicals
vi. Depreciation of farm building and implements
vii. Irrigation charges
viii. Transportation charges
ix. Interest on working capital
x. Miscellaneous expenses

Cost A1: Paid-out costs in cash and kind.
Cost B1: A2 + interest on owned capital (excluding land).
Cost B2: B1 + rental value of owned land.
Cost C2: B2 + imputed family labour.
Cost C3: C2 + 10% managerial cost.

The rental value of land was imputed as one-third of gross output, consistent with local tenancy practices.
Cost of C3 is added in order to provide allowance for managerial functions undertaken by the farmer.

Cost of Production = (C_3 − Value of By-Product)/ Yield per acre

Benefit-Cost Ratio

Benefit Cost ratio was obtained by dividing the gross income by the total cost of cultivation per acre.

$$\text{Cost of Production} = \frac{\text{Cost } C_3 \text{ - Value of By Product}}{\text{Yield/acre}}$$

Monte Carlo Sensitivity Analysis

Monte Carlo simulation is a statistical technique used to estimate the impact of uncertainty in input variables on a model's output by generating a large number of simulations using random draws from specified probability distributions. In the present study, Monte Carlo sensitivity analysis was employed to evaluate the variability in NPV per acre of chilli cultivation due to stochastic changes in output price and fertilizer cost. These variables were identified as key determinants of profitability based on field data.
The formula used for calculating NPV in each simulation was:

NPV_i = (Output $Price_i$ × Yield) − (Fixed Costs + Fertilizer $Cost_i$)

RESULTS AND DISCUSSION

1. **Analysis of Trends in Area, Production, and Productivity of Chillies in Guntur District (2002–2003 to 2021–2022)**

The secondary data on chilli area, production, and productivity in the study area from 2002–2003 to 2021–2022 were collected and analyzed using growth rate analysis.

(i) Growth Rate

The growth rate in area, production, and productivity of chilli was re-estimated, accounting for structural breaks, with the results presented in Tables 1 and 2. The data spans two decades, offering insights into the trends in chilli cultivation in the Guntur district of Andhra Pradesh, Indiastatagri (2023). Between 2002 and 2006, the area under chilli cultivation experienced fluctuations, marked by a significant increase in 2003–2004. This is due to increased demand, and it prompted farmers to expand chilli cultivation areas. However, by 2005–2006, there was a decline in area, reaching its lowest point in 2005–2006 with 41,453 hectares. From the year 2006–2007 onwards, the area consistently increased, peaking in 2021–2022 at 102,523 hectares. This increase indicates a growing interest and economic viability in chilli farming over the years. The peak production of 485,089 metric tons was recorded in 2016–2017, whereas the lowest was 119,700 metric tons in 2002–2003.

Production generally increased over the period, reaching a notable high of 481,584 metric tons in 2019–2020. However, the subsequent decline to 358,831 metric tons in 2021–2022 indicates potential issues affecting yields. Productivity was significantly lowered in the years 2010–2011 and 2012–2013, aligned with below-average rainfall and reported pest infestations. Productivity has shown overall improvement, peaking at 6100 kg/ha in 2020–2021, although it dropped to 3500 kg/ha in the year 2021–2022. This indicates that the 2021–2022 decline was linked to the prevalence of pandemic COVID-19, labour constraints, and erratic rainfall and changes in farming practices. Comparison with Bonigala (2024) revealed cost differences due to inflation, cost conventions (C3 vs full cost), and varietal focus (mixed vs GI-tagged Sannam). The farmers in the study area were increasing the area under cultivation, production, and productivity of chillies due to the favourable climate and an increase in yield by implementing new growing techniques and improved technologies in their fields.

Table 1. Area, Production and productivity of chilli in Guntur District (2002–2022).

Year	Area (Ha)	Production (MTS)	Productivity (Kg/Ha)
2002–2003	59,316	119,700	2018
2003–2004	67,274	338,792	5034
2004–2005	55,805	273,426	4899
2005–2006	41,453	194,251	4686
2006–2007	59,916	288,940	4822
2007–2008	64,000	315,000	4921
2008–2009	63,628	314,379	4940
2009–2010	66,938	361,407	5399
CGR	5.87	6.45	3.29
2010–2011	64,708	219,101	3385
2011–2012	76,124	326,833	4293
2012–2013	120,470	361,411	3000
2013–2014	133,722	401,166	3000
2014–2015	68,927	344,635	5000
2015–2016	68,261	321,244	4710
2016–2017	87,114	485,089	5570
2017–2018	63,107	421,721	6680
2018–2019	78,760	456,808	5800
2019–2020	80,264	481,584	6000
2020–2021	78,512	478,923	6100
2021–2022	102,523	358,831	3500
CGR	7.95	9.14	5.88

Note: Significant at 1 per cent level.

Table 2. Regression Output for CGR Estimation.

Variable	Coefficient	Std. error	t-statistic	*p*-value
In(a)	11.02	0.126	87.46	0.000
T(Inb)	0.045	0.008	5.62	0.000
R-squared	0.803			
F-statistic	31.64			0.000

(ii) Trends in Area, Production, and Productivity of Chilli

The trend line in area, production, and productivity of chilli are presented Figure 1. It was observed that the trend area of chilli had no significant upward or downward trend during the period 2002–2003 to 2010–2011 and in contrast to the earlier years, there is a substantially increasing tendency from 2015–2016 to 2021–2022. The overall trend is upward, with an increase nearly the ending of the period, although frequent changes.

Over the years, there are noticeable variations in production. The periods of 2003–2004, 2013–2014, and 2019–2020, where production levels witnessed significant. increases, were highlighted by the most significant spikes. On the other direction, there were significant reductions in 2004–2005, 2011–2012, and 2021–2022 years. Similar to production, productivity levels likewise show significant compared to the previous changes. Some significant productivity levels increase in the years 2003–2004, 2014–2015, and 2017–2018 and substantial decrease have been seen in the periods 2009–2010, 2012–2013, and 2021–2022. This reduction could be correlated to the period's productivity decline, thereby pointing focus on problems like decreased worker productivity, resource constraints, or external disruptions.

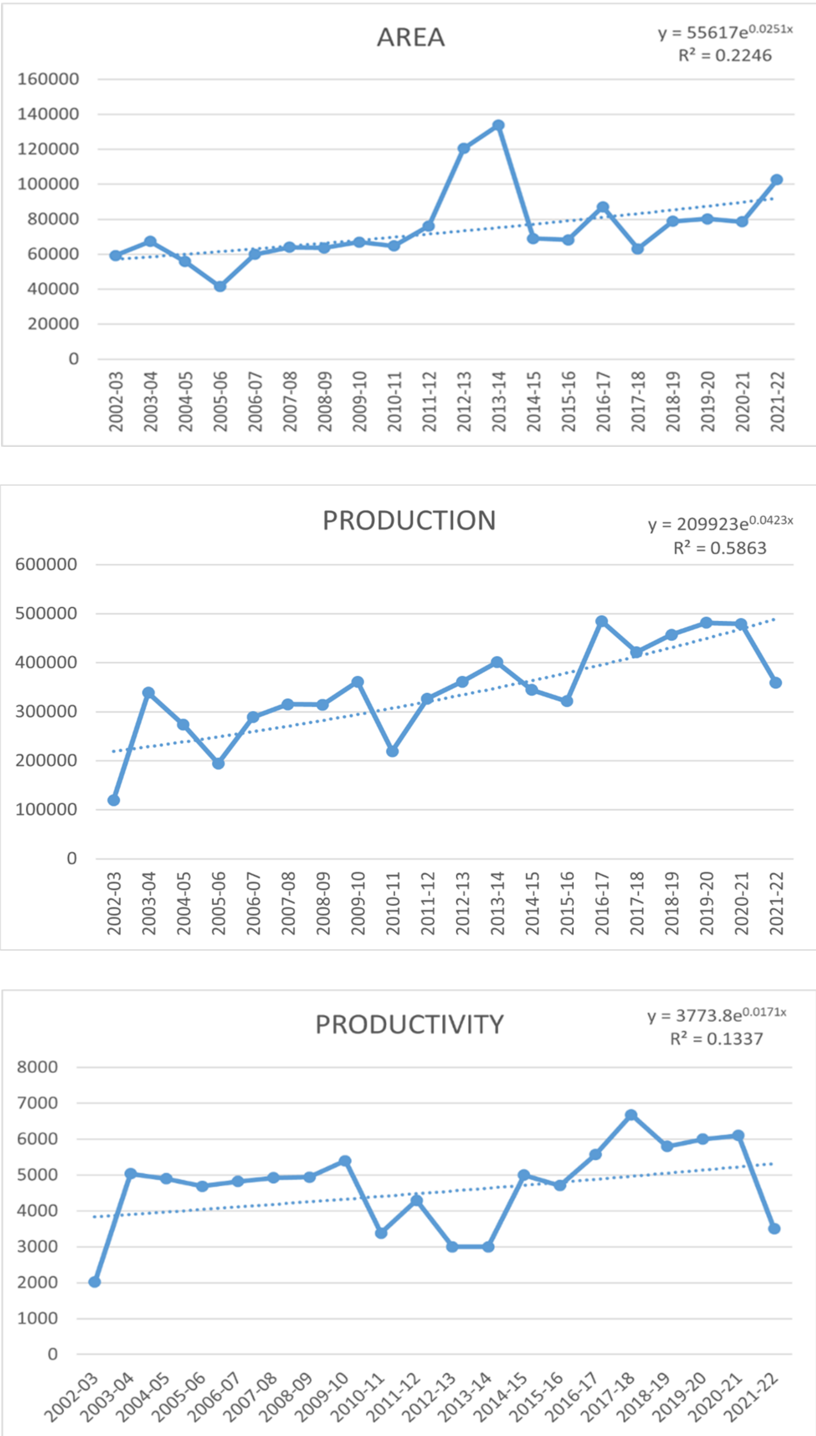

Fig. 1. Trends in Chilli Cultivated Area, Production, and Productivity in Guntur District (2002–2022).

2. Cultivation of Chilli

(i) Varieties Preferred by Sample Farmers in the Study Area

Table 3 and Figure 2 indicate that Guntur Sannam (S4) is the most favoured variety among sample farmers, with 63.33 per cent of respondents choosing it. Guntur Chilli, Guntur Teja (S17), and Guntur 341 are preferred by 8.33 per cent, 15 per cent, and 13.33 per cent of respondents respectively, making up a total of 120 respondents.

Table 3. Varieties Preferred by Sample Farmers.

S. no	Varieties	No. of respondents
1.	Guntur Sannam (S4)	76 (63.33)
2.	Guntur Chilli	10 (8.33)
3.	Guntur Teja (S17)	18 (15.00)
4.	Guntur 341	16 (13.33)
	Total	120 (100)

Note: Figure in the parentheses indicates the percentage to the total.

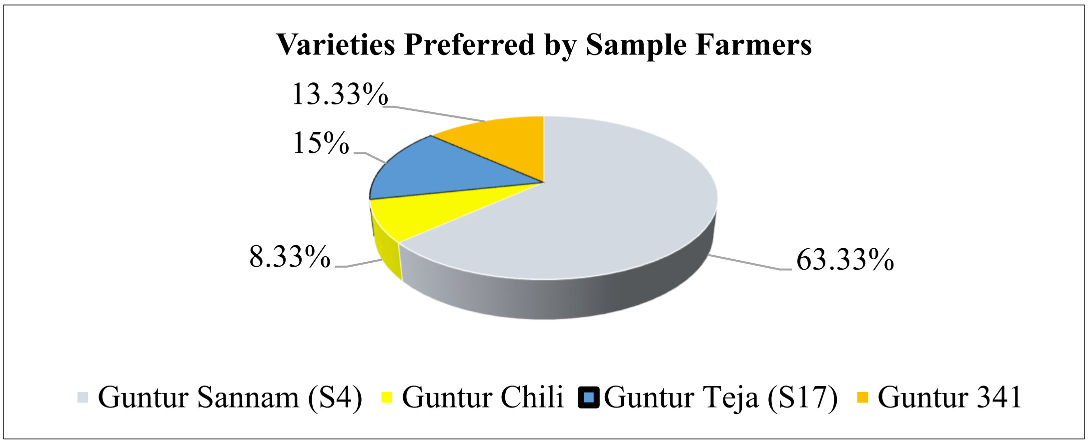

Fig. 2. Varieties Preferred by Sample Farmers.

(ii) Cost and returns of Chilli in the Guntur District

A detailed analysis of costs and returns is calculated to estimate the cost of chilli cultivation in the Guntur district. The estimated costs are presented in Table 4. The primary expense involved seed purchase, accounting for Rs. 2880 per acre, with seed prices ranging up to Rs. 4780 depending on the company, followed by land preparation required a tractor, a total of Rs. 1700 and labour charges accounting for Rs. 1200 per acre. Gypsum was applied at 50 kg per acre for Rs. 1300 and 20 kg of zinc for Rs. 4300. Three days before transplanting, 50 kg of DAP was applied at a cost of ₹1350 per acre. The transplanting costs is Rs. 1040, followed by Irrigation, which was applied four times, requiring three labourers at Rs. 250 per person, accounting for Rs. 3000. Urea and other fertilizers were applied five days after sowing, with costs of R. 360 for 50 kg of Urea and Rs. 1700 for 28 kg of other fertilizers. The total cost of fertilizers was Rs. 9310. Weeding was done manually thrice, requiring six labourers at Rs. 250 each, costing Rs. 4500. Herbicides, including GOAL herbicide (Oxyfluorfen 23.5%) and Dost Super, were applied with a total cost of Rs. 4060, including labour charges, followed by the use of insecticides like Tracer, Rimon, Police, and Regent, which cost Rs. 4710, with labour costs for application estimated at Rs. 570 per acre.

The total operational cost amounted to Rs. 48,900 per acre, and the interest on working capital, calculated at 10 per cent, was Rs. 4890. Depreciation on fixed assets was estimated at Rs. 1805 per acre. The land's rental value, estimated as one-third of the output value, was Rs. 18,890. The imputed value of family labour was Rs. 900 per year. The total cost of cultivation was calculated at Rs. 85,095 per acre. The estimated average yield of chilli per acre was 8 quintals, with an output price of Rs. 21,000 per quintal, equivalent to Rs.160 per/kg. The gross return is estimated at Rs. 168,000, resulting in a net return of Rs. 42,084. The average production cost per/kg of chilli was Rs. 157.40, yielding a net return of 1.334 per rupee invested in the study area.

Table 4. Cost and returns of chilli in the study area. (Rs./Ac.)

Particulars	Quantity with units	Cost
Land preparation		
(a) Human labour	4 labours * Rs. 300/person	1200
(b) Tractor Labour	2 h * Rs. 850/hour	1700
Sowing Seed variety Own seeds	278 1 acre × 12 packets of seed × Rs. 240/per packet Each packet SKU is of 20 grams.	2880
Transplanting	4 female labours* Rs. 260/labour	1040
Irrigation	4Times × 3 labours × Rs. 250 per person	3000
Fertilizers	Gypsum-50 kgs × Rs. 1300/50 kg Zinc-20 kgs × Rs. 4300/20 kg DAP-Rs. 1350/50 kgs Urea-Rs. 360/50 kg 28-Rs. 1700/50 kg 3 labours × Rs. 300/labour	9310
Weedicides	Weeds are Manually removed. 3Times × 6 labours × Rs.250/labour	4500
Herbicide	GOAL (Corteva) Rs. 1150/500 ml Dost Super-Rs. 2150/3.5 Lit 4 labours × Rs. 190/person	4060
Insecticide	Rimon-Rs. 1260/250ml Tracer-Rs. 1900/75ml Police-Rs. 870/80 grams Regent-Rs. 230/Kg 3 labours × Rs 150/person	4710
Harvesting	5 harvests × 7 labours × Rs. 400/Labour	14,000
Other miscellaneous charges	-	2500
Total	-	48,900
Interest on working capital @ 10%		4890
Depreciation on fixed capital		1805
Total cost A_1		55,595
Rent paid for leased–in land	-----	Nil
Total cost A_2	Total cost A_1+Rent paid for leased-inland	55,595
Interest on owned fixed capital @7%		1974
Total cost B_1	Cost A_2 + Interest on owned fixed assets	57,569
Rental value of owned land	1/3 value of output (gr)	56,000
Total cost B_2	Cost B_1 + Rental value of owned land	113,569
Imputed value of family labour		900
Total cost C_1	B1	58,469
Total cost C_2	Cost B_2 + Imputed value of family labour	114,469
Total cost C_3	Cost C_2 × 1.10 (10% of Cost C_2 added to Cost C_2)	125,916
Yield (Quintals)		8
Price (Rs./Quintal)		21,000
Gross returns		168,000
Net returns	GR-C3	42,084
Return per rupee	GR/C3	1.334
Cost of production (Rs./kg)	C3/Yield	157.40

The figure in parentheses indicates the percentage of the total. Note: Using the stated convention that the rental value of owned land equals one-third of gross output, the revised aggregates are: B2 = ₹113,569, C2 = ₹114,469, and C3 = ₹125,916 per acre. At the observed gross return of ₹168,000 (8 quintals × ₹21,000), the net return is ₹42,084 per acre, the benefit–cost ratio is 1.33, and the cost of production is ₹157.4 per kg.

(iii) Output and Returns of Chilli Farmers

From Table 5, it could be seen that the Monte Carlo simulation (10,000 iterations) produced a mean NPV of ₹41,894 per acre with a standard deviation of ₹16,963, closely aligning with the deterministic estimate. Percentile analysis shows limited downside risk, 5th percentile ₹15,396, and substantial upside, 95th percentile ₹70,967. The probability of negative NPV is 0.32%, indicating that chilli cultivation is economically viable in most simulated scenarios. Price and Yield Sensitivity Analysis: Scenario analysis revealed that profitability is highly elastic to price and yield fluctuations (Table 5). At a −15% price and −10% yield, net returns nearly vanish (₹2604; BCR = 1.02). Conversely, under favourable conditions (+15% price and +10% yield), net returns rise to ₹86,604, with BCR improving to 1.69. This reinforces the vulnerability of chilli farmers to market volatility (Table A1).

Table 5. Output and Returns of Chilli Farmers in the Study Area.

S. No.	Particulars	Rs./Acre
1	Yield	8
2	Price per quintal	21,000
3	Gross returns	168,000
4	Total costs	42,084
5	Net returns per rupee	1.334
7	Cost of production (Rs./kg)	157.40

From Table 6 and Figure 3, a Monte Carlo sensitivity analysis was conducted to evaluate the impact of input price and output price variability. It depicts the simulated NPV distribution. The input–output sensitivity shows that output price is the dominant driver (correlation = +0.997), while fertilizer cost plays a secondary role (correlation = −0.093). This underscores the importance of price stabilization mechanisms and marketing interventions in enhancing farm viability. Overall, the findings emphasize the need for price stabilization mechanisms, crop insurance, and efficient marketing systems to safeguard farmer incomes against adverse price shocks, while improved fertilizer use efficiency can yield marginal but positive effects.

Table 6. Monte Carlo Sensitivity Output.

Metric	Value (Rs.)
Mean NPV (per/ac)	41,894
Standard Deviation of NPV	16,963
5th Percentile of NPV	15,396
Median	41,037
9th Percentile of NPV	70,967
P (NPV < 0)	0.32%
Simulation of Count	1000 iterations
Variables simulated	Output price, Fertilizer cost

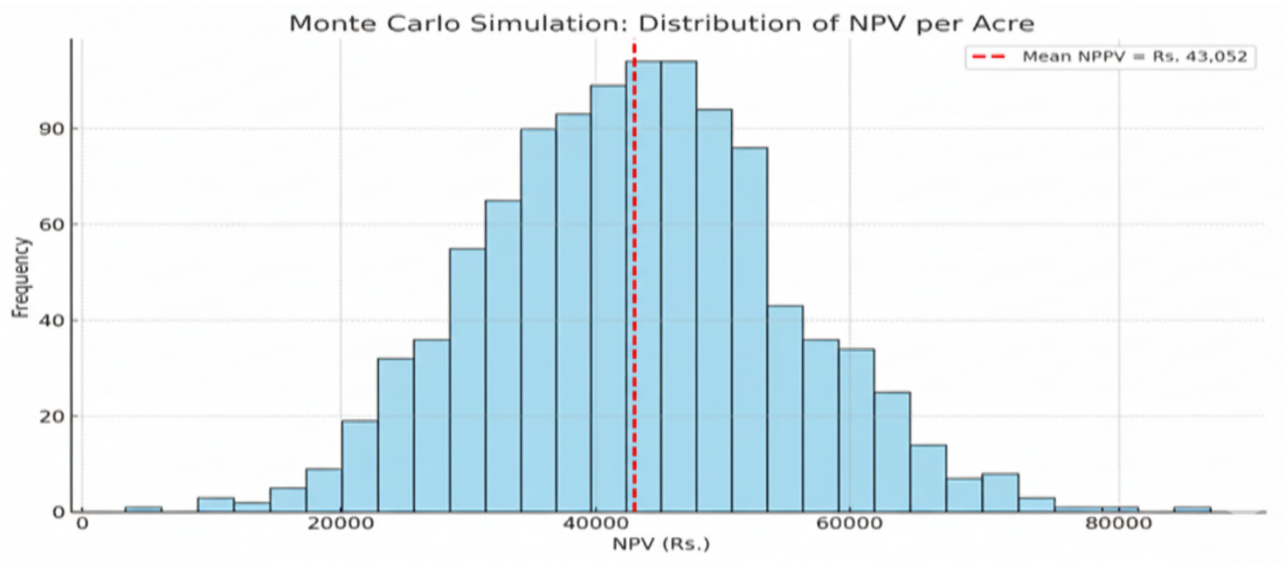

Fig. 3. Bell-shaped histogram showing the simulated distribution of Net Present Value (NPV) per acre.

CONCLUSIONS

The economic analysis of chilli cultivation in the Guntur district of Andhra Pradesh highlights the significant growth in area, production, and productivity over the past two decades. Despite recent fluctuations, particularly in productivity, the overall trend indicates that chilli farming remains a viable and attractive agricultural practice, but input price volatility and environmental shocks significantly affect productivity and profitability. The cost and return analysis of cultivating chilli in the study area shows that though the produce generates a net return of Rs. 42,084 per acre, high input costs, labour costs, and price instability adversely affect the production process. Chilli crop encounters an average production cost of Rs. 157.40/per kilogram. Therefore, utilizing resources efficiently is essential to keeping profits high. Better profits and higher yields were enabled accessible to producers by the increasing demand in chilli production, which has been driven by favourable market conditions and improved farming practices. In spite of these, advancements and recent productivity improvements were limited by challenges, including increased input costs, unstable markets, and environmental constraints. Future strategies should integrate resource optimization, timely market information and climate-resilient practices.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

APPENDIX A

Table A1. Sensitivity Analysis (Price ± 15%, Yield ±10%).

Price change	Yield change	Gross (₹)	Net (₹)	BCR	CoP (₹/kg)
−15%	−10%	128,520	2604	1.021	174.88
−15%	0%	142,800	16,884	1.134	157.40
−15%	+10%	157,080	31,164	1.247	143.09
0%	−10%	151,200	25,284	1.201	174.88
0%	0% (base)	168,000	42,084	1.334	157.40
0%	+10%	184,800	58,884	1.468	143.09
+15%	−10%	173,880	47,964	1.381	174.88
+15%	0%	193,200	67,284	1.534	157.40
+15%	+10%	212,520	86,604	1.688	143.09

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