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Improving farm profitability in BT cotton through enhanced operational efficiency: Empirical evidence from Telangana

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Abstract

The present study was undertaken to analyze the economics, resource use efficiency, adaptation, and mitigation practices of cotton cultivation in Nalgonda in Telangana state, India. Primary data were collected from 135 cotton farmers selected through a multistage sampling procedure. Cotton cultivation was profitable across all farm categories, with net income of ₹26,183 ha⁻¹ on marginal farms, ₹27,795 ha⁻¹ on small farms, and ₹35,529 ha⁻¹ on large farms. The benefit-cost ratio varied from 1.35 to 1.41 across the farm categories. Cobb-Douglas production function revealed that seed, FYM and fertilizers had a significant positive influence on cotton yield, whereas human labour exhibited a significant negative effect. Garrett ranking analysis revealed that adjustment of sowing time based on rainfall pattern was the most preferred climate adaptation strategy. At the same time, minimum tillage practices ranked first among climate change mitigation strategies. Thus, an optimal allocation of productive resources, coupled with scientific crop management practices, could improve resource use efficiency, enhance productivity, and increase the profitability of cotton cultivation in the study area.

Keywords: Benefit-cost ratio, cobb-douglas production function, cotton, resource-use efficiency

Introduction

The adoption and performance of Bt cotton in India, and its commercial release in 2002, marked the beginning of the "Gene Revolution" in Indian agriculture. Bt cotton rapidly expanded to nearly 90% of the country's cotton-growing area due to its potential for improved bollworm control and higher productivity^[1].

India is one of the leading cotton-producing countries in the world, with cultivation in over an area of nearly 125 lakh ha (2025-26). Total cotton production in the country was estimated at 317 lakh bales, which was later revised to 320.5 lakh bales based on improved crop conditions and higher arrivals from major cotton-growing states^[2]. Gujarat ranked first in cotton production, followed by Maharashtra and Telangana during the above period.

Telangana emerged as one of the major cotton-growing states in India, with a cultivated area of 18 lakh ha (2025-26). Cotton production in the state was estimated at 38-40 lakh bales, placing the state in third position among cotton-growing states in the country. According to the Cotton Corporation of India (CCI), the state recorded the highest procurement during the season (2025-26), indicating the importance of cotton cultivation in the state economy^[3].

The adoption of improved cotton technologies increased productivity and farm income in major cotton-growing regions of India.⁴ The profitability largely depends on efficient utilization of inputs such as human labour, fertilizers, irrigation and plant protection chemicals.⁵ Rising input costs, labour scarcity, pest incidence and price fluctuation adversely affected the profitability of cotton in Telangana^[6].

Materials and methodology

A multistage sampling procedure was adopted for the study. Nalgonda was purposively selected owing to its largest area under Bt cotton cultivation in Telangana. Three mandals, viz.,

Narketpally, Munugode, and Chandur, were purposively selected because they accounted for the largest area under cotton cultivation. Three villages were randomly selected from each mandal, and fifteen cotton growers from each village were selected, resulting in a total of 135 samples. They were further categorized into marginal (35), small (54) and large (46) farmers based on their area of cultivation. The cost of cultivation was calculated by using CACP cost concepts. Farm Business Measures are indicators used to evaluate the economic performance, profitability, and efficiency of a farm enterprise. The estimation of resource use efficiency in cotton cultivation was carried out using the Cobb-Douglas production function. A multiple linear regression model was employed to understand the influence of climatic variables on cotton productivity.

Garette ranking analysis was used to find out the adaptation and mitigation strategies followed by farmers.

Results and Discussion Economics of cotton cultivation

The cost analysis of cotton cultivation (Table 1) shows that total cultivation cost rose progressively with farm size. Total cost of cultivation at Cost C3 was estimated at ₹1,17,415 ha⁻¹ on marginal farms, ₹1,19,989 ha⁻¹ on small farms and ₹1,24,654 ha⁻¹ on large farms, as presented in Table 2. The higher cost incurred on large farms was mainly attributed to high expenditure on hired human labour, machine labour, fertilizers, and plant protection chemicals. The total cost of cotton cultivation was ₹97887.50 ha⁻¹, and costs were relatively higher on large farms relative to marginal farms [7].

Table 1: Cost of cotton cultivation (₹/ha)

Particulars	Marginal	Small	Large
Hired labour	38239.44 (35.82)	39002.54 (35.76)	41494.54 (36.62)
Family labour	3389.14 (3.18)	2907.00 (2.66)	2894.02 (2.55)
Total	41628.58 (39.00)	41909.54 (38.42)	44388.56 (39.17)
Hired Bullock labour	1511.06 (1.42)	1550.61 (1.42)	1630.20 (1.44)
Family Bullock labour	658.67 (0.62)	654.55 (0.60)	640.66 (0.57)
Total	2169.73 (2.03)	2205.16 (2.02)	2270.86 (2.00)
Hired machinery	4881.19 (4.57)	5140.27 (4.71)	5434.00 (4.80)
Family machinery	3140.43 (2.94)	3908.41 (3.58)	4254.77 (3.75)
Total	8021.62 (7.52)	9048.68 (8.29)	9688.77 (8.55)
Seed	5539.86 (5.19)	5454.58 (5.00)	5653.62 (4.99)
FYM	3027.51 (2.84)	3146.78 (2.88)	3119.72 (2.75)
Fertilizers	7522.91 (7.05)	7657.00 (7.02)	7608.67 (6.71)
Plant protection	8906.11 (8.34)	8988.06 (8.24)	9015.50 (7.96)
Transport	1417.14 (1.33)	1037.04 (0.95)	1032.61 (0.91)
Total variable cost	78233.47 (73.29)	79446.84 (72.83)	82778.31 (73.04)
Interest on working capital @ 7%	2738.17 (2.57)	2780.64 (2.55)	2897.24 (2.56)
Total variable cost (I)	80971.64 (75.86)	82227.48 (75.38)	85675.55 (75.60)
Rental value of own land	15525.71 (14.55)	16077.87 (14.74)	16689.19 (14.73)
Rental value of leased-in land	6638.13 (6.22)	7410.00 (6.79)	7586.43 (6.69)
Depreciation @ 10%	1262.77 (1.18)	924.32 (0.85)	857.07 (0.76)
Interest on fixed capital @ 10%	2342.66 (2.19)	2441.22 (2.24)	2513.27 (2.22)
Total fixed costs (II)	25769.27 (24.14)	26853.41 (24.62)	27645.95 (24.40)
Total costs (I+II)	106740.91 (100.00)	109080.89 (100.00)	113321.50 (100.00)
Yield (quintals ha ⁻¹)	19.20	19.71	21.00
Price (price per quintal)	7480.86	7496.30	7629.57
Gross income	143598.26	147783.93	160182.72

Note: Figures in parentheses indicate percentage to total

Table 2: Cost concepts in cotton cultivation across different farm categories (₹ ha⁻¹)

Particulars	Marginal	Small	Large
Cost A1	75046.18	75681.84	78743.17
Cost A2	81684.30	83091.84	86329.59
Cost B1	77388.84	78123.06	81256.43
Cost B2	99552.68	101610.93	105532.05
Cost C1	84577.07	85593.02	89045.88
Cost C2	106740.91	109080.89	113321.50
Cost C3	117415.00	119988.98	124653.65

Among various cost components, across all farm-size categories, expenditure on human labour constituted the largest share of the total variable cost. The expenditure ranged from ₹41,628 ha⁻¹ on marginal farms, ₹41,909 ha⁻¹ on small farms and ₹44,388 ha⁻¹ on large farms. Human labour accounted for 39 per cent, 38 per cent and 39 per cent of the total cultivation cost on marginal, small and large farms, respectively, indicating the labour-intensive nature of cotton cultivation. Similar results revealed that labour constituted a major component of cotton cultivation cost in Gujarat [8].

The total variable cost, including interest on working capital, was estimated at ₹80,972 ha⁻¹, ₹82,227 ha⁻¹ and ₹85,675 ha⁻¹ on marginal, small and large farms, respectively. Total fixed cost was estimated at ₹25,769 ha⁻¹ on marginal farms, ₹26,853 ha⁻¹ on small farms and ₹27,646 ha⁻¹ on large farms. The increase in fixed cost with farm size was mainly due to the high

rental value of land and interest on fixed capital. Also brought out the fact that operational and fixed costs increase with expansion in farm size in northern India [9].

The gross income realized from cotton cultivation was highest on large farms (₹1,60,183 ha⁻¹), followed by small farms (₹1,47,784 ha⁻¹) and marginal farms (₹1,43,598 ha⁻¹). Net income was also highest on large farms (₹35,529 ha⁻¹) compared to small (₹27,795 ha⁻¹) and marginal farms (₹26,183 ha⁻¹) as presented in Table 3. Net income was 36 per cent higher in large farms than marginal farms and 28 per cent higher than small farms, indicating the greater profitability of larger farms which indicates higher economies of scale. Similar findings were observed that adoption of High-Density Planting System (HDPS) technology resulted in 6.02 per cent higher net returns in cotton cultivation in Telangana [10].

Table 3: Farm income measures in cotton cultivation (₹ ha⁻¹)

Particulars	Marginal	Small	Large
Yield (quintals ha ⁻¹)	19.20	19.71	21.00
Price (price per quintal)	7480.86	7496.30	7629.57
Gross income	143598.26	147783.93	160182.72
Farm business income	68552.08	72102.09	81439.56
Family labour income	44045.58	46173.00	54650.67
Net income	26183.26	27794.95	35529.07
Farm investment income	61363.85	64632.13	73650.11
B:C ratio	1.35	1.35	1.41

Farm business income and family labour income were also comparatively higher on large farm holdings. The Benefit-Cost ratio was estimated at 1.35, 1.35, and 1.41 for marginal, small, and large farms, respectively, indicating that cotton cultivation was economically viable across all categories of farmers. Similar results were observed B:C ratios ranging from 1.73 to 1.83 in cotton cultivation in Chhattisgarh [7].

The study indicated that cotton cultivation was profitable across all farm categories, though profitability was relatively higher among large farms. Human labour emerged as the major component of cultivation costs, underscoring the need for labour-saving technologies viz., mechanization, and efficient

resource management practices to improve profitability in cotton cultivation.

Resource use efficiency in cotton cultivation

The Cobb-Douglas production function analysis indicated seed, FYM, and fertilizers had a positive influence on cotton production, as shown in Table 4. The coefficient of seed (0.09) was positive and significant, indicating that an increase in seed input increased cotton output. This may be due to the adoption of improved Bt cotton hybrids and better seed quality. Similar observations were reported that improved seed utilization positively influenced cotton productivity in Haryana [5].

Table 4: Resource-use Efficiency of Production Inputs Based on the Cobb-Douglas Production Function

Sl. No.	Independent Variables	Regression Coefficient (b _i)	t-value	Geometric Mean (X _i)	MVP (₹)	MFC (₹)	MVP/MFC	Resource-use efficiency
1	Constant	1.52 (0.49)	3.080	19.9				
2	Human labour (man-days ha ⁻¹)	-0.1132* (0.0661)	-1.713	52.50	-317.44	400	-0.79	Over-utilized
3	Bullock labour (pair-days ha ⁻¹)	0.0218 (0.0287)	0.761	5.50	584.86	800	0.73	Over-utilized
4	Machine labour (hours ha ⁻¹)	0.0292 (0.0306)	0.954	5.60	766.63	2,000	0.38	Over-utilized
5	Seed (kg ha ⁻¹)	0.0903** (0.0435)	2.076	4.30	3,092.70	1,600	1.93	Under-utilized
6	Farmyard	0.1268***	2.860	10.00	1,866.94	1,000	1.87	Under-

	manure (tonnes ha ⁻¹)	(0.0443)						utilized
7	Fertilizers (kg ha ⁻¹)	0.2656*** (0.0700)	3.793	230.20	169.89	72	2.36	Under- utilized
8	Plant protection chemicals (litres or kg ha ⁻¹)	-0.0204 (0.0357)	-0.571	7.10	-422.41	400	-1.06	Over-utilized

Note: Figures in the parentheses indicate their respective standard errors

***Significance at 1% level, **Significance at 5% level, *Significance at 10% level GM - Geometric mean MVP - Marginal Value Product. MFC - Marginal Factor Cost

The coefficients of FYM (0.13) and fertilizers (0.27) were positive and highly significant, indicating that balanced nutrient application enhanced cotton productivity and returns. The coefficient of human labour (-0.11) was negative, indicating that an increase in human labour beyond the optimum level reduced cotton output. This suggests the existence of excess labour use in cotton cultivation, resulting in diminishing marginal productivity of labour. Similar results were observed that manure and fertilizer significantly influenced Bt cotton production ^[11].

The MVP/MFC analysis revealed that human labour, bullock labour, machine labour, and plant protection chemicals were over-utilized, as their MVP/MFC ratios were less than one. In contrast, seed, farmyard manure, and fertilizers were under-utilized, with MVP/MFC ratios greater than one. These findings indicate that reducing the use of over-utilized resources while increasing the use of under-utilized resources towards their economically optimal levels would improve resource-use efficiency and enhance farm profitability. MVP/MFC ratios

greater than unity for human labour (1.44), machine labour (5.07), seed (12.76), and irrigation (1.88), indicating that these resources were underutilized and that increased use could enhance returns ^[12].

The resource-use pattern observed was broadly in conformity with the recommendations prescribed for cotton cultivation in Telangana. The recommended seed rate for hybrid cotton is 1.5-2.0 kg ha⁻¹, whereas the sample farmers used 3.95 kg ha⁻¹ on marginal farms, 4.00 kg ha⁻¹ on small farms and 5.13 kg ha⁻¹ on large farms, indicating relatively higher quantity of seed used. The recommended application of farmyard manure is 10 t ha⁻¹; however, the quantity applied by farmers varied from 8.54 t ha⁻¹ on marginal farms to 10.25 t ha⁻¹ on small farms and 11.28 t ha⁻¹ on large farms. Fertilizer use ranged from 223.67 kg ha⁻¹ on small farms to 251.94 kg ha⁻¹ on marginal farms and 226.59 kg ha⁻¹ on large farms, reflecting substantial investment in nutrient management. Plant protection chemicals were applied at 6.90, 6.79, and 7.09 litres ha⁻¹ on marginal, small, and large farms, respectively, indicating the importance of pest management in cotton production presented in Table 5.

Table 5: Input-wise cost of cotton cultivation across different farm categories

Material cost	Marginal			Small			Large		
	Quantity	Price per unit	Total	Quantity	Price per unit	Total	Quantity	Price per unit	Total
Seed (kg ha ⁻¹)	3.95	1401.79	5539.86	4	1362.86	5454.58	5.13	1102.71	5653.62
FYM (tonnes ha ⁻¹)	8.54	354.55	3027.51	10.25	307.15	3146.78	11.28	276.67	3119.72
Fertilizers (kg ha ⁻¹)	251.94	29.86	7522.91	223.67	34.23	7657	226.59	33.58	7608.67
Plant protection (kg ha ⁻¹)	5.65	1577.7	8906.11	7.04	1275.99	8988.06	9.24	976.23	9015.5
Total			24996.4			25246.4			25397.5

Therefore, the study suggested that efficient and scientific utilization of productive resources such as quality seed, FYM and fertilizers could improve cotton productivity and profitability, while excessive use of labour and plant protection chemicals should be minimized to enhance the efficiency of resource utilization.

Adaptation and Mitigation Strategies

The Garette ranking analysis shown in Table 6 indicated that adjustment of sowing time based on rainfall pattern was the most widely adopted climate change adaptation strategy among cotton growers, with the highest mean score (70.59), followed by adoption of Bt cotton (69.85) and use of weather forecasts and agro-advisory services (60.96). These findings suggest that farmers predominantly rely on adaptive measures that enhance resilience to climatic variability while requiring relatively low additional investment. Changes in fertilizer and nutrient

application practices (40.59), intercropping with cotton (40.37), and soil moisture conservation practices (38.59) exhibited moderate levels of adoption. In contrast, Integrated Pest Management (IPM) (26.15) and drip or sprinkler irrigation (12.74) were the least adopted practices, which may be attributed to higher investment requirements and technical complexity. Overall, the results indicate that cotton growers preferentially adopt economically feasible and management-oriented adaptation strategies over capital-intensive technological interventions. The adaptation strategies, including adjustments in sowing time, planting density, irrigation, and plant protection, can help minimize these adverse effects ^[13]. The interaction between sowing date and climate significantly influenced cotton yield and resource use efficiency. Extreme rainfall reduced seed cotton yield, but appropriate management of sowing dates mitigated yield losses ^[14].

Table 6: Adaptation strategies

Adaptation strategies	Mean Score	Rank
Adoption of Bt cotton	69.85	2
Adjustment of sowing time based on rainfall pattern	70.59	1
Use of drip or sprinkler irrigation	12.74	8
Integrated Pest Management (IPM)	26.15	7
Intercropping with cotton	40.37	5
Soil moisture conservation practices	38.59	6
Use of weather forecast and agro-advisory services	60.96	3
Change in fertilizer and nutrient application practices	40.59	4

The ranking of climate change mitigation practices shown in Table 7 revealed that conservation tillage/minimum tillage practices were the most preferred strategy among cotton growers, recording the highest mean score (76.39). This was followed by the application of nano urea and nano DAP (59.07), Integrated Nutrient Management (INM) practices (57.59), use of bio-fertilizers (55.01), and adoption of the High-Density Planting System (HDPS) (53.22), indicating moderate to high adoption of practices aimed at improving input use efficiency. In contrast, efficient irrigation and energy-saving practices (44.77), crop rotation (39.20), and crop residue management through incorporation instead of burning (33.66) received lower mean

scores. The relatively lower adoption of these practices may be attributed to resource constraints, limited awareness, and operational challenges. Overall, the findings suggest that cotton growers predominantly adopt economically viable mitigation practices, improve resource-use efficiency, and are compatible with existing production systems. The importance of soil management and tillage practices in improving cotton productivity under changing climatic conditions ^[15]. The potential of genomic approaches to enhance stress resilience and reported that rising temperatures, altered rainfall patterns, and extreme weather events adversely affect cotton yield ^[16].

Table 7: Mitigation strategies

Mitigations strategies	Mean Score	Rank
Crop rotation	39.2	7
Adoption of high-density planting system (HDPS)	53.22	5
Integrated Nutrient Management (INM) practices	57.59	3
Use of bio-fertilizers	55.01	4
Application of nano urea and nano DAP	59.07	2
Conservation tillage / minimum tillage practices	76.39	1
Efficient irrigation and energy-saving practices	44.77	6
Crop residue management (Incorporation instead of burning)	33.66	8

Conclusion: Cotton cultivation was profitable across all farm categories, with relatively higher returns observed on large farms due to better resource utilization. Human labour constituted the major share of cultivation cost, reflecting the labour-intensive nature of cotton farming. The study showed that balanced input use, efficient resource allocation, and adoption of improved production technologies are essential for enhancing cotton productivity and profitability. Therefore, strengthening extension support, promoting scientific cultivation practices, and encouraging efficient input management would contribute to sustainable cotton production.

Authors' contributions

CS executed the research work, designed the methodology and drafted the initial manuscript. CP supervised the entire research work. MN & BP assisted in data analysis. PA critically reviewed and revised the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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