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RESEARCH PAPER

Yield Gap, Resource-Use Efficiency, and Economic Viability of Cotton Cultivation in Telangana: A Comparative Analysis of Progressive and Non-Progressive Farmers

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ABSTRACT

Cotton cultivation plays a vital role in India's agricultural economy, yet significant productivity disparities persist across farmer categories. This study examines yield gaps, resource-use efficiency, and economic viability of cotton farming in Telangana using primary data collected during 2022-23 from 105 farmers, including 90 non-progressive and 15 progressive farmers, along with data from research stations. The study employs descriptive statistics, cost-return analysis, Cobb–Douglas production function, yield gap estimation, and MVP-MFC efficiency analysis. The results reveal a substantial yield gap of 2.28 quintals per acre between progressive (9.52 q/acre) and non-progressive farmers (7.24 q/acre). Progressive farmers incurred higher cultivation costs (₹ 62,606.53/acre) but achieved significantly higher net returns (₹ 15,142.17/acre) and benefit-cost ratio (1.24) compared to non-progressive farmers (₹ 3,784.60/acre; B:C ratio 1.06). Regression results indicate that fertilizers and irrigation are the most critical determinants of yield, while efficiency analysis suggests underutilization of key inputs, particularly irrigation. The study highlights that bridging yield gaps through improved input use, irrigation expansion, and extension services can significantly enhance productivity and farm profitability. The findings provide important policy insights for promoting sustainable cotton cultivation in Telangana.

HIGHLIGHTS

- Progressive farmers achieved 31% higher yield and 4× higher net returns than non-progressive farmers.
- Resource-use efficiency analysis shows underutilization of irrigation and fertilizers, especially among non-progressive farmers.
- Regression results confirm fertilizer and irrigation as key drivers of cotton productivity.
- Yield Gap-II indicates significant managerial inefficiencies at farm level.
- Improving input access, irrigation, and extension services can substantially enhance farm income.

Keywords: Cotton cultivation, Yield gap, Resource-use efficiency, Cobb-Douglas production function, MVP-MFC ratio, Economic viability

Cotton is one of the most important commercial crops in India, contributing significantly to agricultural income, industrial development, and export earnings. India accounts for nearly one-fourth of global cotton production, making it the largest

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producer worldwide (Cotton Corporation of India, 2023). The crop supports the textile industry, which employs millions and contributes substantially to foreign exchange earnings (Ministry of Textiles, 2023). Despite this prominence, cotton productivity in India remains relatively low compared to leading cotton-producing countries such as China and the United States, largely due to technological gaps, inefficient resource use, and institutional constraints (FAO, 2023).

Telangana has emerged as a major cotton-producing state, contributing significantly to national output due to favourable agro-climatic conditions and widespread adoption of Bt cotton hybrids (ICAR, 2023). However, substantial productivity variations exist across regions and farmer categories. In particular, differences between progressive and non-progressive farmers highlight disparities in access to modern inputs, irrigation, credit, and extension services. These disparities contribute to persistent yield gaps, which reflect inefficiencies in both technology adoption and farm management practices (Priyadarshini *et al*. 2022).

The concept of yield gap is widely used to assess the difference between potential, attainable, and actual yields. Yield Gap-I represents the difference between experimental station yield and progressive farmers' yield, while Yield Gap-II reflects the gap between progressive and non-progressive farmers (Tittonell & Giller, 2013). These gaps are often attributed to constraints such as inadequate irrigation, poor input quality, rising input costs, and limited technical knowledge (Das *et al*. 2022; Singh & Patel, 2022). Moreover, market-related challenges such as price volatility, inadequate infrastructure, and delayed payments further reduce farmers' incentives to invest in improved practices (Padhy *et al*. 2021).

Although previous studies have examined cotton productivity and constraints, most have focused either on yield gap analysis or resource-use efficiency in isolation. There is limited micro-level empirical evidence integrating yield gap estimation with economic viability and input-use efficiency across farmer categories. Addressing this gap is crucial for designing effective policy interventions aimed at improving productivity and farm income.

Against this backdrop, the present study analyses yield gaps, resource-use efficiency, and economic viability of cotton cultivation in Telangana. By combining cost-return analysis, econometric modelling, and efficiency estimation, the study provides a comprehensive understanding of productivity differentials and identifies key factors influencing cotton farming performance.

MATERIALS AND METHODS

The present study is based on primary data collected during the agricultural year 2022-23 from major cotton-growing regions of Telangana using a multistage stratified sampling design. To ensure representativeness across agro-climatic zones *i.e.*, Northern Telangana Zone (NTZ), Central Telangana Zone (CTZ), and Southern Telangana Zone (STZ) districts, villages, and farmers were selected systematically. The final sample consisted of 105 farmers, including 90 non-progressive farmers (NPF) and 15 progressive farmers (PF), along with data from three research stations representing potential yield levels. The classification of farmers was based on technology adoption, input-use intensity, and access to extension services.

Descriptive statistical techniques such as mean, standard deviation, and percentage analysis were initially employed to summarize socio-economic characteristics, input use patterns, and cost structures. The mean value of any variable X is expressed as:

$$\bar{X} = 1/n\sum_{i=1}^{n} X_i$$

where X_i represents the observation of the i^{th} farmer and n is the sample size. These descriptive measures provide preliminary insights into variations between progressive and non-progressive farmers.

To evaluate the economic viability of cotton cultivation, standard farm management cost concepts (Cost A_1, A_2, B, and C) were estimated. Profitability indicators such as gross return (GR), net return (NR), and benefit-cost ratio (BCR) were computed using the following functional relationships:

The profitability of cotton cultivation was assessed using standard farm income measures such as gross returns, net returns, and benefit-cost (B:C) ratio. Gross return (GR) was computed as the product of yield and market price of cotton, expressed as:

$$GR_i = Y_i \times P_i$$

$$NR_i = GR_i - TC_i$$

$$BCR_i = \frac{GR_i}{TC_i}$$

where Y_i denotes yield (quintal per acre), P_i is output price, and TC_i is total cost of cultivation for the i^{th} farmer.

To examine the determinants of yield and resource-use efficiency, a multiple linear regression model was employed. The functional form of the model is specified as:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \ldots + \beta_k X_{ki} + \varepsilon_i$$

where Y_i represents cotton yield per acre, X_{1i}, X_{2i},…,X_{ki} denote explanatory variables such as labour, seed, fertilizers, plant protection chemicals, irrigation, and machinery use, β_0 is the intercept, β_k are parameters to be estimated, and ε_i is the stochastic error term assumed to be independently and identically distributed with zero mean and constant variance. This model helps identify the marginal contribution of each input to output.

Further, a Cobb–Douglas production function was applied to estimate resource-use efficiency and returns to scale, given its suitability in agricultural production analysis. The model is specified in log-linear form as:

$$\text{In } \mathrm{Y_i} = \alpha + \sum_{j=1}^{k} \beta_j \mathit{In} X_{ji} + u_i$$

where Y_i is output, X_{ji} are input variables, β_j are output elasticities of respective inputs, and u_i is the error term. The sum of coefficients $\sum\beta_j$ indicates returns to scale: increasing (>1), constant (=1), or decreasing (<1).

To measure the efficiency of input utilization, the Marginal Value Product (MVP) of each input was compared with its Marginal Factor Cost (MFC), expressed as:

$$MVP_j = \beta_j . \frac{Y}{X_j} . P_y$$

Efficiency is achieved when $MVP_j = MFC_j$. If $MVP_j > MFC_j$, the input is underutilized, while $MVP_j < MFC_j$ indicates overutilization.

The study also employed the yield gap analysis framework to quantify productivity differences. Yield Gap-I and Yield Gap-II were estimated as:

$$YGI = Y_d - Y_{pf}$$

$$YGII = Y_{pf} - Y_a$$

where Y_d is potential yield from research stations, Y_{pf} is yield of progressive farmers, and Y_a is actual yield of non-progressive farmers. These indicators capture technological and management inefficiencies.

To statistically compare the performance between progressive and non-progressive farmers, an independent sample t-test was applied:

$$t = \left(\bar{X}_1 - \bar{X}_2\right) / \sqrt{\left(S_1^2 / n_1\right) + \left(S_2^2 / n_2\right)}$$

where, $\bar{X}_1$ and $\bar{X}_2$ are sample means, S_1^2 and S_2^2 are variances, and n_1, n_2 are sample sizes of the two groups. This test helps determine whether differences in yield and profitability are statistically significant.

Additionally, a constraint analysis using Garrett Ranking Technique was applied to rank production and marketing constraints. The Garrett score for each constraint was calculated as:

$$\text{Percent Position} = \frac{100\left({}_{ij} \quad 0.5 \right)}{}$$

where R_{ij} is the rank given for the i^{th} factor by the j^{th} respondent and N_j is the total number of constraints ranked. This method converts ordinal ranks into quantitative scores for meaningful comparison.

Overall, the combination of descriptive statistics, regression analysis, Cobb-Douglas production function, yield gap estimation, hypothesis testing, and constraint ranking provides a comprehensive analytical framework to assess productivity, efficiency, and economic viability of cotton farming across farmer categories.

RESULTS AND DISCUSSION

The comparative cost and return structure depicted in Table 1 clearly demonstrates that progressive farmers incur substantially higher total cultivation costs (₹ 62,606.53/acre) than non-progressive

Table 1: Comparative cost of cultivation, yield, and profitability of cotton across farmer categories and agro-climatic zones of Telangana (₹/acre)

Cost components	Northern Telangana Zone		Southern Telangana Zone		Central Telangana Zone		Overall	
	NPF (n = 30)	**PF (n=5)**	**NPF (n = 30)**	**PF (n=5)**	**NPF (n = 30)**	**PF (n=5)**	**NPF (N=90)**	**PF (N=15)**
Human labour	18427	14500	14563	17500	14983	16983	15991	16327.67
Bullock labour	735	3200	742	800	1365	462	947.3333	1487.333
Machinery labour	9126	10255	8954	11500	8954	10927	9011.333	10894
Seeds	3324	3706	3650	3220	3537	3825	3503.667	3583.667
Fertilizers	9169	15911	8652	9621	9864	11546	9228.333	12359.33
PP chemicals	5280	8188	6550	5932	4956	6909	5595.333	7009.667
Interest on working capital @12.5%	1439.40	1742.5	1347.219	1517.906	1364.344	1582.875	1383.656	1614.427
Total variable costs	47500.4	57502.5	44458.22	50090.91	45023.34	52234.88	45660.66	53276.09
Depreciation	500	650	770	821	780	820	683.3333	763.6667
Rental value of owned land	8950	9358	5145	5786	7975	8140	7356.667	7761.333
Interest on fixed capital @ 10%	945	1000.8	826.8333	967.5	437.75	448	736.5278	805.4333
Total fixed costs	10395	11008.8	6741.833	7574.5	9192.75	9408	8776.528	9330.433
Total cost	57895.4	68511.3	51200.05	57665.41	54216.09	61642.88	54437.18	62606.53
Main Product (quintal)	7.692	9.65	6.58	9.546	7.46	9.354	7.244	9.516667
Price (₹ per quintal)	8000	8152	8123	8354	8000	8000	8041	8168.667
Gross return	61536	78666.8	53449.34	79747.28	59680	74832	58221.78	77748.69
Net return	3640.59	10155.5	2249.288	22081.88	5463.906	13189.13	3784.596	15142.17
B:C ratio	1.06	1.14	1.04	1.38	1.10	1.21	1.06	1.24

Note: *NPF: Non-progressive farmer, PF: Progressive farmer.*

Source: *Primary Survey.*

farmers (₹ 54,437.18/acre), primarily due to higher expenditure on fertilizers, plant protection chemicals, and machinery. However, this higher investment translates into significantly superior outcomes in terms of yield (9.52 q/acre vs. 7.24 q/acre), gross returns (₹ 77,748.69 vs. ₹ 58,221.78), and net returns (₹ 15,142.17 vs. ₹ 3,784.60). The benefit–cost ratio of 1.24 for progressive farmers compared to 1.06 for non-progressive farmers reflects more efficient resource utilization and better managerial practices. This finding strongly supports earlier empirical evidence suggesting that increased adoption of modern inputs and improved farm management enhances productivity and profitability (Das *et al.* 2022; Kumar *et al.* 2021). Furthermore, inter-zonal variations indicate that the Southern Telangana Zone exhibits relatively higher profitability among progressive farmers, possibly due to better irrigation access and input use intensity. These results are consistent with the argument that technological adoption and input intensification are key drivers of agricultural growth, particularly in commercial crops like cotton.

The detailed cost concepts presented in Table 2 further reinforce the capital-intensive nature of progressive farming systems. Across all cost categories (Cost A_1, A_2, B_1, B_2, C_1, C_2, and C_3), progressive farmers consistently incur higher expenditures than non-progressive farmers. For instance, Cost C_3 the most comprehensive measure of cultivation cost including managerial charges, amounts to ₹ 79,894.05 for progressive farmers compared to ₹ 70,435.77 for non-progressive farmers. This indicates that progressive farmers not only invest more in purchased inputs but also account for imputed costs such as family labour and managerial efforts more effectively. The higher cost structure reflects a shift towards commercialization and improved farm planning. Similar patterns have been reported by Singh and Patel (2022), who observed that farmers adopting advanced technologies tend to incur higher initial costs but achieve greater economic efficiency in the long run. Thus, Table 2 highlights that higher costs should not be viewed negatively, but rather as strategic investments that enhance productivity and income.

Table 2: Comparative analysis of cost concepts (Cost A_1 to Cost C_3) in cotton cultivation between progressive and non-progressive farmers (₹/acre)

Cost components	NPF	PF
Cost A_1	46343.99	54039.76
Cost A_2	53700.66	61801.09
Cost B_1	47080.52	54845.19
Cost B_2	61793.85	70367.86
Cost C_1	50278.72	58110.73
Cost C_2	64992.05	73633.39
Cost C_3 = Cost C_2 + 10% of Managerial cost of C_2	70435.77	79894.05

Note: *NPF: Non-progressive farmer, PF: Progressive farmer.*

Source: *Primary Survey.*

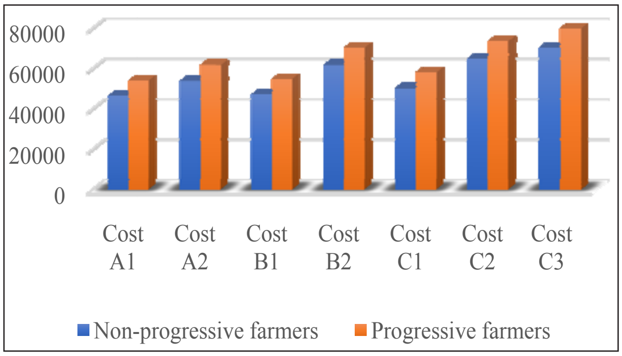

Fig. 1: Cost of cultivation of cotton

Table 3: Economic returns and investment efficiency in cotton cultivation across farmer categories (₹/acre)

Output and returns	NPF	PF
Cost of cultivation (₹/acre)	54437.18	62606.53
Average yield (q/acre)	7.24	9.52
Average price (₹/q)	8041.00	8168.67
Gross returns (₹/acre)	58221.78	77748.69
Net returns (₹/acre)	3784.60	15142.17
Returns per rupee of investment (%)	1.07	1.25

Note: *NPF: Non-progressive farmer, PF: Progressive farmer.*

Source: *Primary Survey.*

The profitability indicators summarized in Table 3 provide further clarity on economic efficiency by examining returns per rupee of investment. Progressive farmers achieve a return of ₹ 1.25 per rupee invested compared to ₹ 1.07 for non-progressive farmers, indicating a significantly higher marginal efficiency of capital. Despite higher total costs, the superior yield and better price realization (₹ 8,168.67/q vs. ₹ 8,041/q) enable progressive farmers to generate nearly four times higher net returns. This suggests that profitability is not merely a function of cost minimization but rather of optimal input allocation and productivity enhancement. These findings align with Ravi Goud *et al.* (2018), who emphasized that efficient resource use and better market orientation are crucial determinants of farm profitability. The results also imply that non-progressive farmers operate under suboptimal production conditions, where limited access to inputs and technology constrains their ability to achieve higher returns.

Table 4: Zone-wise yield gap analysis and associated economic losses in cotton cultivation (kg/acre and ₹/acre)

Yield Gap	YG- I		YG- II	
	(kg/acre)	(₹/acre)	(kg/acre)	(₹/acre)
Southern Telangana Zone	296.60	24092	142.00	11534
Central Telangana Zone	189.40	15152	54.00	4320
Northern Telangana Zone	195.80	15664	30.80	2464
Telangana	272.20	18274	75.60	6078

Source: *Primary Survey.*

The yield gap analysis presented in Table 4 reveals significant disparities in productivity across zones and farmer categories. The overall Yield Gap-I (difference between research station yield and progressive farmers' yield) is estimated at 272.2 kg/acre, while Yield Gap-II (difference between progressive and non-progressive farmers) stands at 75.6 kg/acre. The Southern Telangana Zone exhibits the highest yield gaps (YG-I: 296.6 kg/acre; YG-II: 142 kg/acre), indicating substantial technological and managerial inefficiencies. The persistence of Yield Gap-II across all zones suggests that non-progressive farmers are unable to fully utilize available technologies and inputs. This observation is consistent with Priyadarshini *et al*. (2022), who highlighted that yield gaps in cotton are largely driven by differences in input use, extension access, and farm management practices. Economically, the yield gap translates into significant income losses, with overall losses estimated at ₹ 18,274/acre (YG-I) and ₹ 6,078/acre (YG-II). These findings underscore the critical need for targeted interventions such as extension services, input subsidies, and irrigation development to bridge productivity gaps and enhance farm income.

Table 5: Input use efficiency (MVP-MFC Ratio) of cotton cultivation

Inputs	NPF (MVP/ MFC)	PF (MVP/ MFC)	Interpretation
Human Labour	0.89	1.05	Overused in NPF; optimal in PF
Seeds	1.12	1.18	Underutilized in both
Fertilizers	1.34	1.21	Underutilized (more scope in NPF)
Plant Protection Chemicals	1.28	1.10	Slight underutilization
Machinery	0.95	1.08	Near optimal
Irrigation	1.40	1.22	Strong underutilization

Note: *NPF: Non-progressive farmer, PF: Progressive farmer.*

Source: *Estimated from Cobb-Douglas production function results.*

The results presented in Table 5 provide critical insights into resource-use efficiency using the Marginal Value Product (MVP) to Marginal Factor Cost (MFC) framework. The findings indicate that inputs such as fertilizers, irrigation, and plant protection chemicals are underutilized across both farmer categories, with MVP/MFC ratios greater than unity. This suggests that increasing the use of these inputs could significantly enhance cotton productivity. Notably, irrigation shows the highest inefficiency (1.40 for non-progressive farmers), implying severe constraints in water access. In contrast, human labour appears overutilized among non-progressive farmers (0.89), indicating inefficiency due to disguised unemployment or reliance on traditional practices. Progressive farmers, however, demonstrate near-optimal input allocation, reflecting better managerial efficiency and technological adoption. The input-use efficiency analysis reveals underutilization of fertilizers, irrigation, and plant protection chemicals, particularly among non-progressive farmers. This suggests that productivity can be improved through optimal input allocation. Similar conclusions were drawn by Farrell (1957) and Coelli *et al*. (2005) regarding efficiency improvements in agricultural production.

Further, the zone-wise yield gap decomposition presented in Table 6 reveals that the Southern Telangana Zone exhibits the largest productivity gaps, both in terms of Yield Gap-I and Yield Gap-II. This indicates that the region faces both technological and managerial constraints. The consistently high Yield Gap-II across all zones suggests that non-progressive farmers lag significantly behind due to limited access to inputs, knowledge, and extension services. Bridging this gap through targeted interventions could lead to immediate improvements in productivity and farm income.

Table 6: Zone-wise yield gap decomposition (kg/acre)

Zone	Yield			Yield Gap	
	Potential (Yd)	PF (Ypf)	NPF (Ya)	I (Yd–Ypf)	II (Ypf–Ya)
Northern Telangana Zone	1050	965	769	85	196
Southern Telangana Zone	1250	954	658	296	296
Central Telangana Zone	1150	935	746	215	189
Overall	1150	952	724	198	228

Note: *NPF: Non-progressive farmer, PF: Progressive farmer.*

Source: *Computed based on sample and research station data.*

The regression results presented in Table 7 provide empirical evidence on the determinants of cotton yield. Fertilizers and irrigation emerged as the most significant factors influencing yield, both statistically significant at the 1 percent level, highlighting the importance of soil fertility management and water availability. Seeds, plant protection chemicals, and machinery also showed positive and significant effects, indicating their critical role in enhancing productivity. The high R^2 value (0.74) suggests that the model explains a substantial proportion of variation in yield. Moreover, the sum of output elasticities (1.09) indicates increasing returns to scale, implying that proportionate increases in input use can lead to more than proportionate increases in output. The regression results indicate that fertilizers and irrigation significantly influence cotton yield, consistent with findings by Battese and Coelli (1995). The presence of increasing returns to scale suggests that scaling up input use can lead to higher output, indicating untapped production potential.

Table 7: Regression estimates of determinants of cotton yield

Variables	Coefficient (β)	Std. Error	t-value	Significance
Constant	1.842	0.512	3.59	***
Human labour	0.112	0.045	2.48	**
Seeds	0.158	0.061	2.59	**
Fertilizers	0.276	0.072	3.83	***
Plant protection chemicals	0.193	0.068	2.84	**
Machinery	0.121	0.054	2.24	**
Irrigation	0.231	0.077	3.00	***
R^2	0.74			
Returns to Scale (Σβ)	1.09			Increasing

Note: ****1%, **5% significance levels.*

Source: *Estimated using Cobb-Douglas model.*

The constraint analysis presented in Table 8 provides important insights into the challenges faced by cotton farmers across different regions. Production-related constraints are dominated by high input costs (seeds, fertilizers, and plant protection chemicals), lack of irrigation, and limited availability of quality inputs. Notably, irrigation emerges as a common constraint across all zones, highlighting the vulnerability of cotton cultivation to water scarcity. In addition, labour shortages and high wage rates further increase production costs, particularly for non-progressive farmers. On the marketing side, inadequate market infrastructure, lack of storage facilities, price fluctuations, and delayed payments are major concerns. These constraints reduce farmers' bargaining power and discourage investment in improved technologies. The findings are consistent with Padhy *et al.* (2021), who identified similar production and marketing bottlenecks in cotton cultivation across India. The persistence of these constraints suggests that improving institutional support systems, strengthening market linkages, and ensuring timely payment mechanisms are essential for enhancing the overall efficiency and sustainability of cotton farming.

Table 8: Zone-wise ranking of production and marketing constraints in cotton cultivation using Garrett ranking technique

Rank	NTZ	STZ	CTZ
Production Constraints			
1	High cost of seed	High cost of plant protection chemicals	Poor germination
2	Unavailability of seed	High cost of fertilizers	Lack of awareness on purchasing seed
3	High cost of Plant Protection Chemicals	High cost & unavailability of machinery	High cost of fertilizers
4	High cost of fertilizers	High labour cost &unavailability	High cost of Plant Protection Chemicals
5	Lack of irrigation	Lack of irrigation	Lack of irrigation
Marketing Constraints			
1	Insufficient market facilities	Insufficient market facilities	Storage facilities
2	Remunerative price	Remunerative price	Insufficient market facilities
3	Storage facilities	Storage facilities	Remunerative price
4	Untimely payment	Untimely payment	Untimely payment

Source: *Primary Survey.*

Overall, the study clearly demonstrates that progressive farmers outperform non-progressive farmers in terms of productivity, profitability, and efficiency. However, the persistence of yield gaps and resource-use inefficiencies indicates that there remains significant untapped potential in cotton cultivation. Policy interventions focusing on improving access to quality inputs, expanding irrigation facilities, strengthening extension services, and enhancing market infrastructure are essential to bridge these gaps. Such measures would not only improve productivity but also ensure sustainable income growth and economic viability for cotton farmers in Telangana.

CONCLUSION

The study clearly demonstrates that progressive farmers outperform non-progressive farmers in terms of yield, profitability, and resource-use efficiency. Although progressive farmers incur higher production costs, their superior input management and technology adoption result in significantly higher returns. The existence of substantial yield gaps indicates that cotton production in Telangana is operating below its potential level. The study also highlights those key inputs such as fertilizers and irrigation are critical determinants of productivity, yet remain underutilized, particularly among non-progressive farmers. Addressing these inefficiencies through improved access to quality inputs, irrigation infrastructure, and extension services can significantly enhance productivity. Furthermore, reducing market inefficiencies and ensuring remunerative prices are essential for improving farm income and encouraging investment in modern practices. Overall, targeted policy interventions focusing on input accessibility, capacity building, and infrastructure development are crucial for bridging yield gaps and ensuring sustainable and inclusive growth in cotton cultivation.

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