International Journal for Research in Agricultural and Food Science

Published by: **Green Publication Services**
ISSN (Online): **2208-2719**
Volume 12 Issue 01 March 2026

RELATIONSHIP BETWEEN AGRICULTURAL MANAGEMENT PRACTICES AND CROP PRODUCTIVITY

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ABSTRACT

The present study was based on a quantitative, retrospective data design that focused on the relationship between agricultural management practices and cotton productivity for the five major cotton-producing states of India. Analysis was done using Indian Ministry of Agriculture Five-State Cotton Data for Gujarat, Madhya Pradesh, Karnataka, Maharashtra and Andhra Pradesh for the period 1999-2015 and up to 85 state-year observations. Descriptive statistics, correlation analysis and multivariable panel regression were employed to assess the relationship between the cotton yield and the use of Bt cotton, fertilizer, insecticide, irrigation, input cost, cultivated area and rain. The average yield of cotton was 348.35 ± 163.86 kg/ha and the average percentage of area covered by Bt cotton was 47.11% of the total area. Bt adoption and fertilizer use had high positive bivariate correlations with yield, while insecticide use and irrigation had lower positive correlations with yield. In the adjusted model, annual rainfall was still a meaningful positive predictor of cotton yield, and a strong positive temporal trend was seen, whereas the use of Bt, fertilizer, and insecticides, and cultivated area, were not independently meaningful. This last model accounted for 81.1% of the variation in yield. From these results, cotton productivity is the function of various management practices and environmental conditions along with other technological changes occurring in the agricultural system. So integrated and resource-efficient management is crucial for enhancing cotton productivity sustainably.

Keywords: Cotton productivity; Agricultural management practices; Bt cotton; Fertilizer use; Rainfall

Article Type: **Research**
Doi: **10.53555/gafs.v12i1.2575**
Received: **9/02/2026,** Revised: **10/03/2026**, Accepted: **18/03/2026**, Published: **25/03/2026**

1.Introduction

Productivity is the foundation of food and fiber security, rural livelihoods and economic sustainability of agriculture. Soil, water and other natural resources conservation have thus become a central goal of sustainable agricultural development along with increased production. Sustainable intensification highlights the need to increase yield within a given area of land and agricultural resource utilisation without compromising or degrading the environment to an unacceptable degree (Cassman & Grassini, 2020). The productivity of crops does not depend solely on natural soil and climatic factors, but also on the efficiency of farmers in using the resources available. The long-term evidence shows that agricultural management significantly alter soil properties and hence the productive potential of agricultural land (Bai et al., 2018). Soil quality itself is an interplay between physical, chemical and biological processes, which affect nutrient availability, water retention and crop performance (Bunemann et al., 2018). Hence, the knowledge of management–productivity relationships is pertinent in distinguishing practices which can sustain agricultural production under more efficient use of resources.

Agricultural management includes decisions about applying nutrients, controlling pests and weeds, irrigation, plant density, seed technology and other agricultural inputs. These practices can be integrated appropriately to enhance the use of resources and the yield of crops. In cotton production, better weed control, including the use of herbicides in relation to efficient irrigation can minimize crop weed competition, thereby helping sustain cotton production (Hakoomat et al., 2017). Nutrient management is also critical as the productivity of cotton is dependent on good and balanced nutrient availability. Studies show that high-density planting with optimized N application can help to achieve competitive yields with higher economic returns (Dai et al., 2017). Drip fertigation can also help in making nutrients available to the crop by managing the fertilizer inputs in line with the water requirement of the crop including under Bt cotton production system (Harish et al., 2017). The results show that productivity is a function of the quantity and efficiency of agricultural inputs used.

Availability of water is another important crop determinant. Water productivity can be improved by efficient irrigation systems, which can also minimize wasted water. Drip irrigation has shown great promise in improving water productivity of cotton (Cetin & Kara, 2019) and deficit irrigation based on cotton crop growth stage offers opportunities to optimise water use without a commensurate decrease in yield (Himanshu et al., 2019). Water-efficient irrigation strategies for cotton production have also been effective using model-based assessment (Garibay et al., 2019). The evidence from other cropping systems also shows that drip fertigation can increase both biophysical and economic water productivity (Brar et al., 2022) and precision irrigation coupled with a suitable cropping system can help in more sustainable use of water for agriculture (Brar et al., 2022). Moreover, irrigation management has significant impacts on water use and crop production under different climatic and soil-water conditions (Dar et al., 2017) and water use indicators are useful for water allocation at the farm level (Fernández et al., 2020). These relationships are further complicated by climatic variability because of the fact that fluctuations in temperatures and precipitation can impact cotton yield and crop water demand (Chen et al., 2019). Further, cotton genotypes also showed variation in drought tolerance, suggesting that the response of the crop to water stress depends on both the environmental factors and the genetic traits (Gondal et al., 2021).

Cotton is an important economic commercial crop in India with varying production levels across different areas due to differences in the level of rainfall, availability of irrigation, use of inputs, adoption of technology, production management, etc. While individual practices like irrigation, nutrient management, weed control, drought response and water-use efficiency have been studied in relation to cotton, much fewer studies have considered multiple agricultural management factors together across the major cotton-producing areas. This requires an integrated analysis that can separate the relative impacts of management and environment on the productivity differences observed.

In view of this, the study attempts to investigate the association between agricultural management and cotton yield in major cotton-producing states of India. Namely, to analyze cotton productivity trends, the relationship of yield to agricultural inputs such as fertilizer, insecticide, improved seeds, irrigation and others, the effect of rainfall and environmental conditions on yield, and the most important factors in cotton productivity. The results should give evidence for more efficient, resource-saving and productivity-oriented management of cotton.

2. Materials and Methods

2.1 Research Design

The study employed a quantitative, retrospective data design to investigate the relationship between farming management practices and cotton productivity in main cotton-producing states in India. The unit of analysis was the state-year.

2.2 Dataset and Data Source

It was based on the Indian Ministry of Agriculture Five-State Cotton Data, which included data of Gujarat, Madhya Pradesh, Karnataka, Maharashtra and Andhra Pradesh between the years 1999 and 2015

(Gutierrez et al., 2023). The data set had a maximum of 85 observations (state-year) and consisted of cotton yield, agricultural inputs, irrigation, rainfall, cultivated acreage, and economic indicators.

2.3 Study Variables

The dependent variable was cotton yield (kilograms/hectare). The variables in agricultural management were the percentage of Bt cotton area, fertilizer application, insecticide application, irrigation, cost of seed, cost of fertilizer, cost of insecticides, and cost of labor. Control variables were cotton cultivation area and rainfall. Supplementary descriptive interpretation was done using lint price and net profit.

2.4 Data Preparation

The data blocks regarding the states were merged into one panel dataset. Measurement units and variable names were standardized and the data were filtered to eliminate duplicate entries, missing data, inconsistent data and implausible data. Complete-case analysis was used to address any missing data of the variables used in a statistical model. The potential outliers were not removed when they were plausible agricultural conditions.

2.5 Descriptive Analysis

Mean, standard deviation, minimum, maximum, median, and interquartile range were computed to determine the descriptive statistics of all significant variables where necessary. The distribution of cotton yield, Bt adoption, fertilizer use, insecticide use, irrigation, and rainfall state-wise and year-wise were analyzed to determine spatial and temporal patterns.

2.6 Association Analysis

Correlation analysis was used to determine the bivariate relationships among agricultural management practices and cotton productivity. Pearson correlation coefficients were used in continuous variables that were roughly normally distributed with Spearman correlation coefficients being used in instances where the distributional assumptions were not met. Causes of multicollinearity were also looked at by determining the existence of association between the explanatory variables.

2.7 Regression Analysis

The panel regression was done multivariately and cotton yield was considered as the outcome variable. Significant agricultural management variables such as adoption of Bt cotton, use of fertilizers, use of insecticides and measures of input costs were tested and adjustment of rainfall and cultivated area was made. It was assumed that the persistent regional variations and changes over the study period were explained by state and temporal effects. When there was a need, reduced models were employed to prevent overfitting and high levels of multicollinearity.

2.8 Statistical Analysis and Model Diagnostics

Python was used to perform statistical analyses. Statistical significance was set to $p < 0.05$, and the results were presented in the form of regression coefficients, standard errors, 95% intervals, and p-values. The R2, adjusted R2 and the total F-statistic were used to determine model performance. Normality and heteroscedasticity were assessed using residual diagnostics, and multicollinearity was assessed using variance inflation factors. Where necessary, strong standard errors were used. All the results were discussed as associations, but not causal effects due to the nature of observation of the data set.

3. Results

3.1 Descriptive Characteristics of Agricultural Production

The analysis data comprised 85 state-years of 5 cotton-producing states in the period between 1999 and 2015. The cotton yield had 84 observations and a mean of 348.35 + 163.86 kg/ha with a range of 84 to 689 kg/ha. The average cotton growing land was 1.63 million ha, and Bt cotton occupied an average of 47.11% of the cultivated land. The average fertilizer and insecticide applications in the field were 141.50 kg/ha and 0.66 kg/ha, respectively. The average annual precipitation was 952.76 mm. The descriptive traits are given in Table 1.

Table 1. Descriptive Characteristics of Cotton Production and Agricultural Management Variables

Variable	N	Mean	SD	Minimum	Median	Maximum
Cotton yield (kg/ha)	84	348.35	163.86	84.00	319.50	689.00
Cotton area (million ha)	83	1.63	1.18	0.31	1.13	4.21
Bt cotton area (%)	84	47.11	40.36	0.00	57.65	99.30
Seed cost (Rs/ha)	80	2,161.59	1,050.04	756.00	2,031.19	4,008.48
Insecticide cost (Rs/ha)	84	1,631.58	1,130.44	51.00	1,295.50	5,944.00
Insecticide use (kg/ha)	80	0.66	0.39	0.07	0.57	2.13

Fertilizer use (kg/ha)	82	141.50	62.67	28.00	133.00	273.00
Fertilizer cost (Rs/ha)	84	3,672.19	2,579.06	546.00	2,765.50	10,684.00
Labor cost (Rs/ha)	84	11,122.52	8,112.15	1,659.00	7,590.50	30,827.00
Irrigated area (%)	82	33.80	22.56	2.63	27.20	60.00
Annual rainfall (mm)	81	952.76	94.59	544.00	965.90	1,087.30

3.2 Patterns of Agricultural Management Practices

The management practices in agriculture were quite different during the study period. The greatest temporal shift was found in the case of Bt cotton adoption which ranged between virtually no adoption at the beginning of the study period to over 90 percent of the adoption in a few states at the end of the study period. There was also increased spending on fertilizers, labor expenses and seed expenses, but the extent varied across states over a period of time. Irrigation was more spatially than temporally variable with the average irrigated area of cotton varying between 2.63% in Maharashtra and 60.00% in Madhya Pradesh. Figure 1 shows the significant growth in the adoption of Bt cotton in the five states.

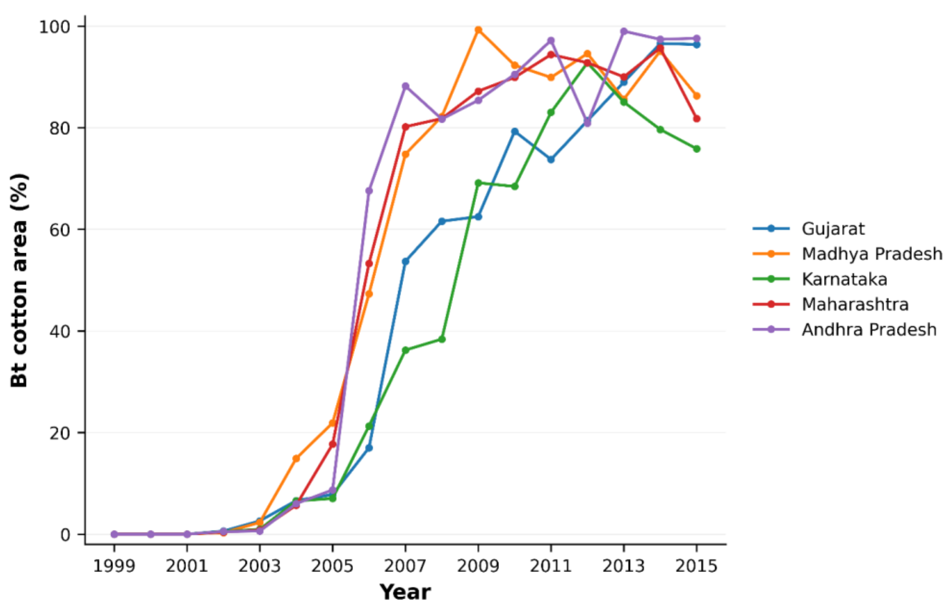

Figure 1. Bt Cotton Adoption Across Five Cotton-Producing States of India

3.3 Cotton Productivity Across States and Years

The five states had significantly different cotton productivity. Gujarat had the maximum mean yield of 480.06 kg/ha, and then Andhra Pradesh with 401.41 kg/ha. The lowest average yield was found in Maharashtra (247.65 kg/ha). The highest yield was also witnessed in Gujarat at 689 kg/ha. Mostly, productivity was on the upward trend during the study period, but there was considerable variation between years. Between the first and the last available observation, there was an increase in yield of about 180.0 percent in Gujarat, 275.2 percent in Madhya Pradesh, 156.0 percent in Karnataka, 87.0 percent in Maharashtra and 84.7 percent in Andhra Pradesh. According to Table 2, the cotton productivity and agricultural management characteristics differed significantly among the five states with Gujarat having the highest mean cotton yield and Maharashtra the lowest.

Table 2. State-Wise Cotton Productivity and Major Agricultural Management Characteristics

State	Mean yield (kg/ha)	SD	Minimum	Maximum	Mean Bt area (%)	Fertilizer (kg/ha)	Insecticide (kg/ha)	Irrigated area (%)
Andhra Pradesh	401.41	105.26	230	588	53.02	206.12	0.94	19.72
Gujarat	480.06	200.80	122	689	39.52	142.31	0.80	58.70
Karnataka	311.06	118.12	142	530	39.11	103.82	0.38	27.20
Madhya Pradesh	309.29	187.28	84	615	52.16	103.12	0.63	60.00
Maharashtra	247.65	84.63	99	373	51.28	153.71	0.52	2.63

3.4 Correlation Between Agricultural Management Practices and Crop Productivity

The bivariate analysis revealed that there were a number of agricultural management variables that were positively correlated with cotton productivity. The adoption of Bt cotton had a very positive relationship with yield ($r = 0.643$, $p < 0.001$). There was also a positive correlation between fertilizer application and yield ($r = 0.522$, $p < 0.001$) and less significant but statistically significant correlations between insecticide use ($r = 0.259$, $p = 0.021$) and irrigation ($r = 0.264$, $p = 0.016$). Among expenditure indicators, labor cost demonstrated the strongest correlation with productivity ($r = 0.673$, $p < 0.001$), followed by seed cost ($r = 0.661$, $p < 0.001$), fertilizer cost ($r = 0.590$, $p < 0.001$), and insecticide cost ($r = 0.561$, $p < 0.001$). Conversely, the analysis of cotton area and annual rainfall was not significant with the yield in the unadjusted analysis. The entire correlation structure is shown in Figure 2.

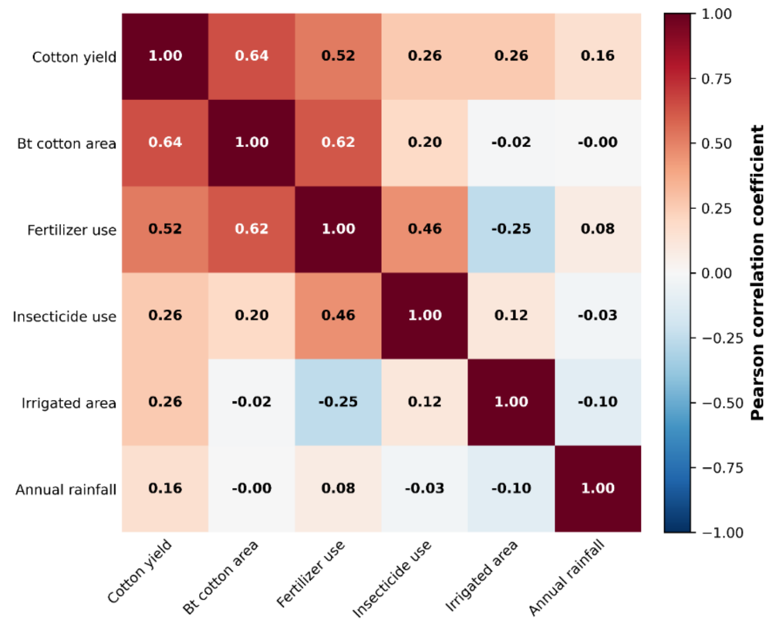

Figure 2. Correlation Matrix of Cotton Productivity and Agricultural Management Variables

3.5 Effect of Bt Cotton Adoption on Productivity

Productivity was a strong correlate of Bt cotton adoption in the unadjusted model. There was an estimated 2.61 kg/ha increase in cotton yield for every one percent of Bt cotton grown (95% CI: 1.97–3.25, $p<0.001$). Even after adjusting for interstate persistence, the association was still there, with a value of 2.80 kg/ha per percentage point (95% CI: 2.33–3.27; $p < 0.001$). With the inclusion of both state effects as well as the temporal trend, however, the Bt coefficient was reduced to 0.26 kg/ha and was not significant ($p = 0.669$). This attenuation suggests that the apparent strong crude association between Bt application and yield was partially attributed to the overall increase in productivity over the years. Bt cotton adoption was significantly positively associated with productivity in the unadjusted and state-adjusted models and then was statistically insignificant when adjusted for both state and temporal effects in the state and time-adjusted model as shown in Table 3.

Table 3. Association Between Bt Cotton Adoption and Cotton Productivity

Model	N	Bt coefficient (kg/ha per 1% increase)	Robust SE	95% CI	p-value	R^2
Unadjusted	84	2.610	0.327	1.970 to 3.250	<0.001	0.413
State-adjusted	84	2.798	0.241	2.325 to 3.271	<0.001	0.709
State + time adjusted	84	0.263	0.617	−0.946 to 1.472	0.669	0.775

3.6 Effects of Fertilizer, Insecticide, and Irrigation

The three direct agricultural input variables studied had a bivariate association with fertilizer use exhibiting the highest correlation ($r = 0.522$, $P<0.001$). There was a positive, but not as strong a correlation between yield and insecticide application and percentage irrigated. When state, rainfall, and temporal effects were considered, fertilizer application ($B = -0.31$, $p = 0.247$) and insecticide application ($B = -17.25$, $p = 0.513$) were not independently associated with productivity. The coefficient of irrigation did not show much temporal variation within states, but showed big differences between them, and was therefore not interpreted as an independent causal effect. Figure 3 shows the relative bivariate relationships of cotton yield with fertilizer, insecticide and irrigation.

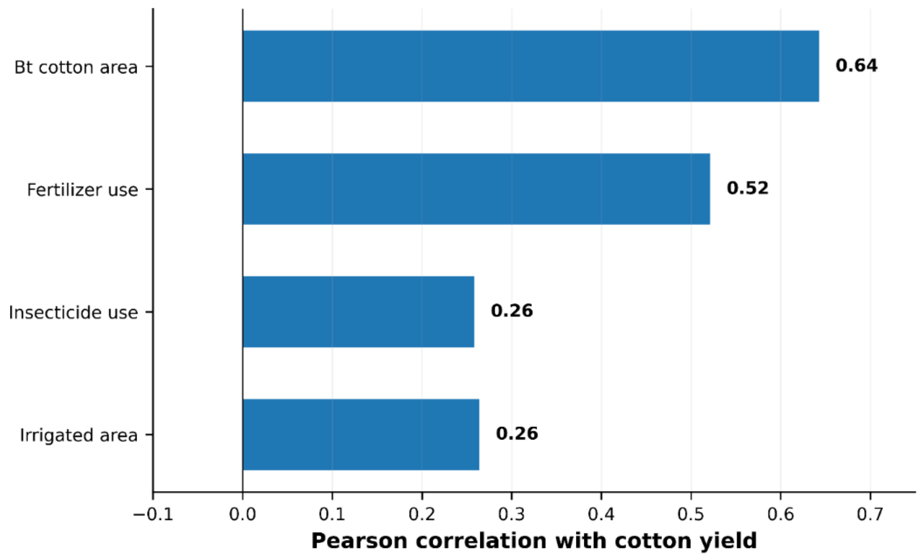

Figure 3. Associations of Major Agricultural Input-Management Practices with Cotton Yield

3.7 Multivariable Regression Analysis

The final multivariable panel regression model consisted of Bt cotton adoption, fertilizer application, insecticide application, cultivated area, annual rainfall, state effects, and the temporal trend. The model explained 81.1% of the variability in cotton yield ($R^2 = 0.811$; adjusted $R^2 = 0.784$). Annual rainfall was independently and positively associated with yield (B = 0.322 kg/ha per mm, 95% CI: 0.118–0.526, $p = 0.002$). A large increase with time, of about 25.81 kg/ha per year (after adjustment, $p < 0.001$) was also observed. After simultaneous adjustment, Bt, fertilizer, insecticide and cultivated area were not individually significant. However, adjusted productivity was significantly lower in Karnataka, Madhya Pradesh and Maharashtra as compared to Andhra Pradesh. The multivariable panel regression in Table 4 accounted for 81.1% of the variation in cotton yields, with annual rainfall and the time trend proving to be important positive factors once management and state-level factors were controlled for.

Table 4. Multivariable Panel Regression Predicting Cotton Productivity

Predictor	B	Robust SE	95% CI	p-value
Bt cotton area (%)	0.092	0.600	−1.084 to 1.268	0.878
Fertilizer use (kg/ha)	−0.364	0.288	−0.928 to 0.199	0.205

Insecticide use (kg/ha)	−10.319	27.776	−64.758 to 44.120	0.710
Cotton area (million ha)	17.989	34.909	−50.430 to 86.409	0.606
Annual rainfall (mm)	0.322	0.104	0.118 to 0.526	0.002
Year trend	25.807	5.840	14.362 to 37.253	<0.001
Gujarat vs. Andhra Pradesh	46.054	49.255	−50.484 to 142.593	0.350
Karnataka vs. Andhra Pradesh	−125.192	43.871	−211.178 to −39.206	0.004
Madhya Pradesh vs. Andhra Pradesh	−127.648	32.885	−192.101 to −63.195	<0.001
Maharashtra vs. Andhra Pradesh	−212.038	81.202	−371.192 to −52.884	0.009

Model statistics: $N = 80$; $R^2 = 0.811$; adjusted $R^2 = 0.784$; robust standard errors used.

3.8 Summary of Major Findings

Productivity of cotton was generally higher in the study period, and varied significantly by state. In the bivariate analyses, Bt cotton adoption, fertilizer use, insecticide use, irrigation, and agricultural input spending were positively associated with productivity. The multivariate results, however, showed that the relationships differed significantly by state level and time. The broad positive trend in cotton productivity over the years (as measured by the strong positive year effect) was an additional positive environmental predictor, suggesting a greater cotton productivity improvement over time than was accounted for by any single input variable. The final model had good explanatory power and predicted yield values were generally in good agreement with observed values (as shown in Figure 4).

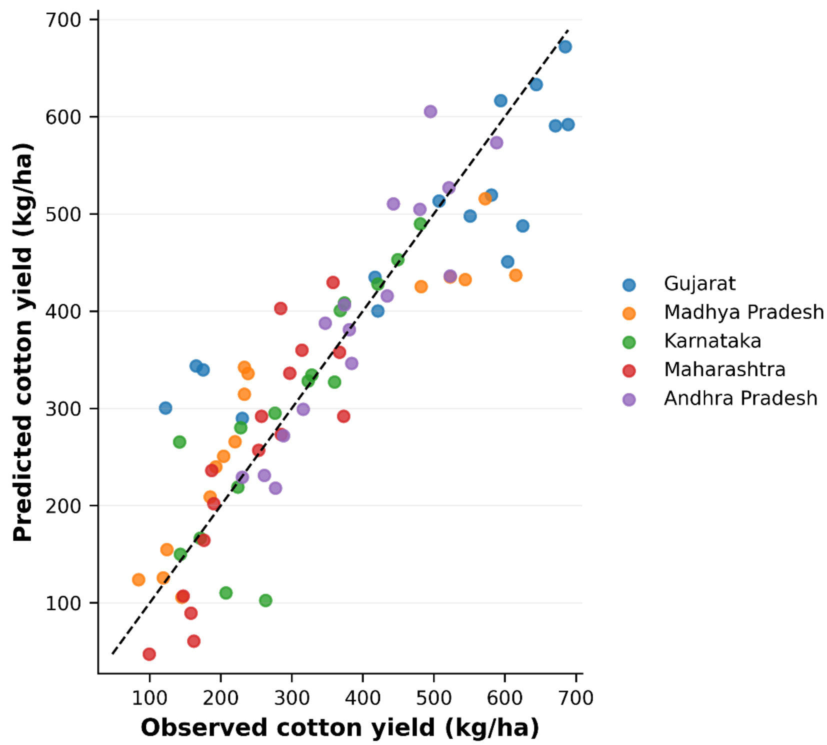

Figure 4. Observed and Predicted Cotton Yield from the Multivariable Panel Regression Model

4. Discussion

The results indicate that there were several agricultural management and environmental variables associated with cotton productivity in the bivariate and adjusted analyses, but the significance varied. Most individual management variables were however, insignificant after adjusting for state, time, rainfall and other inputs. This means that cotton productivity is affected by interacting technological, environmental and management influences, not a single input. This multi-dimensional management is aligned with sustainable intensification principles that encourage coordination of resource use (Pretty et al., 2018).

The unadjusted relationship between Bt cotton and yield was highly positive ($r = 0.643$, $p < 0.001$), and for every percentage point increase in Bt area, the yields rose by an average of 2.61 kg/ha initially. This association was, however, not significant after the state and temporal trends were adjusted for. So, the rise in Bt use did not stand out as a significant factor explaining productivity growth, but instead complemented other technological and agronomic advances. This interpretation is supported by evidence that long-term impacts of Bt cotton rely on complementary management and production conditions in different regions (Peshin et al., 2021). Effective intensification and resource management in these systems can also improve productivity in Bt-based systems (Rajpoot et al., 2021).

In the case of cotton, the application of fertilizer was positively correlated with yield ($r = 0.522$, $p < 0.001$) but was not statistically significant. Application of optimized N and irrigation combinations has improved yield of seed cotton and fiber quality (Hou et al., 2021). In like manner, fertigation can have an impact on yield, soil fertility and nutrient availability (Magare et al., 2018) and efficient N management is needed to enhance cotton production sustainability (Macdonald et al., 2018). Soil quality and environmental performance can be improved as well as yield with integrated nutrient management (Paramesh et al., 2023).

Application of insecticide showed a slight positive bivariate association with yield ($r = 0.259$, $p = 0.021$), but was not significant when multivariable adjusted. The finding indicates that insecticide alone is not sufficient to ensure high productivity and that the effectiveness of pest management is influenced by pest pressure, timing, technology and other agronomic factors. The adoption of Bt cotton also change the requirement of pesticides, further emphasizing the need to look at the use of chemical inputs in the broader production system (Peshin et al., 2021).

Previous studies have confirmed that irrigation scheduling has a significant impact on cotton water productivity (Koudahe et al., 2021) and drip fertigation improve both water-use efficiency and N-use efficiency (Singh et al., 2018). Seed cotton performance may also be affected by surface and subsurface drip irrigation in Indian conditions (Neelakanth et al., 2019). In addition, the potential productivity of mulching and the potential of precision water management have been shown (O'Shaughnessy et al., 2023; Prajapati & Subbaiah, 2018).

The differences in state and differences in time observed are consistent with the findings that cotton productivity can be affected by local management and environment. Crop modeling in North-Western India has shown that phenology, growth conditions and yield of cotton interacted significantly (Mishra et al., 2021). Based on international evidence, planting density and sowing date significantly affect lint yield (Khan et al., 2017). Thus, much of the temporal effect seen in the current analysis may represent several concurrent gains that were not measured by the management variables.

The results are in favor of integrated than input-intensive cotton management. Efficient fertilizer, pest and water management strategies should be considered with proper technology adoption by farmers and agricultural planners. Precision irrigation and balanced nutrient input are critical for enhancing productivity and reducing resource losses (Hou et al., 2021; Singh et al., 2018). This should be accompanied by a sustainable agricultural redesign that emphasizes productivity as well as using resources efficiently and improving environmental outcomes (Pretty et al., 2018).

One of the key advantages of this study was the longitudinal comparison of five important Indian cotton-producing states from 1999 to 2015, allowing management, environmental, and temporal factors to be taken simultaneously. Farm-level variation, however, is obscured by the relatively small state-level sample size, which reduces the power of the statistics. Within-state differences were minimal for irrigation and factors not measured may partly account for the large time effect. Additionally, the results are limited to cotton and cannot be extrapolated to other crops without further research. However, the analysis supports experimental studies indicating the potential of integrated cotton management to enhance productivity and resource use efficiency.

5. Conclusion

This study shows that multiple factors, ranging from agricultural management practices to environmental conditions and changes in the temporal domain are responsible for cotton productivity in the major cotton-producing states of India. At the bivariate level, results indicated that adoption of Bt cotton, use of fertilizer, insecticide, irrigation and input expenditure had positive association with the cotton yield, showing that intensification of management generally went with higher productivity. After controlling for state, rainfall, temporal trend and other production factors, however, most individual management variables were no longer significant. Annual rainfall was still an important positive yield predictor and the strong positive year effect suggested that wider technological, agronomic and structural developments over time also contributed to productivity improvements. The results of this study indicate that cotton productivity is not simply a matter of any one agricultural input but rather a combination of seed technology, nutrients, insecticide, water and climatic resource management. The study thus suggests an integrated and resource saving way for cotton production than only input intensification. More attention should be given to managing nutrients, efficient irrigation, proper pest management and adaptive management due to rainfall variability for farmers and agricultural planners. Future investigations should include farm-level observations, greater samples, soil properties, management timing, and other climatic factors to enhance causal interpretation and to extend the applicability of the conclusions.

References

1. Bai, Z., Caspari, T., Gonzalez, M. R., Batjes, N. H., Mäder, P., Bünemann, E. K., de Goede, R., Brussaard, L.,

Xu, M., & Ferreira, C. S. S. (2018). Effects of agricultural management practices on soil quality: A review of long-term experiments for Europe and China. Agriculture, Ecosystems & Environment, 265, 1–7.

2. Brar, A. S., Kaur, K., Sindhu, V. K., Tsolakis, N., & Srai, J. S. (2022). Sustainable water use through multiple cropping systems and precision irrigation. Journal of Cleaner Production, 333, 130117.
3. Bunemann, E. K., Bongiorno, G., Bai, Z. G., Creamer, R., De Deyn, G. B., de Goede, R. G. M., Fleskens, L., Geissen, V., Kuijper, T. W. M., & Mäder, P. (2018). Soil quality-A critical review. Soil Biology and Biochemistry, 120, 105–125.
4. Cassman, K. G., & Grassini, P. (2020). A global perspective on sustainable intensification research. Nature Sustainability, 3(4), 262–268.
5. Cetin, O., & Kara, A. (2019). Assesment of water productivity using different drip irrigation systems for cotton. Agricultural Water Management, 223, 105693.
6. Chen, X., Qi, Z., Gui, D., Gu, Z., Ma, L., Zeng, F., & Li, L. (2019). Simulating impacts of climate change on cotton yield and water requirement using RZWQM2. Agricultural Water Management, 222, 231–241.
7. Dai, J., Li, W., Zhang, D., Tang, W., Li, Z., Lu, H., Kong, X., Luo, Z., Xu, S., & Xin, C. (2017). Competitive yield and economic benefits of cotton achieved through a combination of extensive pruning and a reduced nitrogen rate at high plant density. Field Crops Research, 209, 65–72.
8. Dar, E. A., Brar, A. S., & Singh, K. B. (2017). Water use and productivity of drip irrigated wheat under variable climatic and soil moisture regimes in North-West, India. Agriculture, Ecosystems & Environment, 248, 9–19.
9. Fernández, J. E., Alcon, F., Diaz-Espejo, A., Hernandez-Santana, V., & Cuevas, M. V. (2020). Water use indicators and economic analysis for on-farm irrigation decision: A case study of a super high density olive tree orchard. Agricultural Water Management, 237, 106074.
10. Garibay, V. M., Kothari, K., Ale, S., Gitz III, D. C., Morgan, G. D., & Munster, C. L. (2019). Determining water-use-efficient irrigation strategies for cotton using the DSSAT CSM CROPGRO-cotton model evaluated with in-season data. Agricultural Water Management, 223, 105695.
11. Gondal, M. R., Saleem, M. Y., Rizvi, S. A., Riaz, A., Naseem, W., Muhammad, G., Hayat, S., & Iqbal, M. (2021). Assessment of drought tolerance in various cotton genotypes under simulated osmotic settings. https://pdfs.semanticscholar.org/429f/693e6e34b3d8010f99a7f31535c305deb350.pdf
12. Gutierrez, A. P., Kenmore, P. E., & Luigi, P. (2023). Cotton data for the Indian states of Andhra Pradesh, Gujarat, Karnataka, Maharashtra, and Madhya Pradesh for years 1999-2014. https://doi.org/10.5281/zenodo.8325341

13. Hakoomat, A., Arooj, M., Sarwar, N., Areeb, A., Shahzad, A. N., & Hussain, S. (2017). Application of pre and post emergence herbicide under improved field irrigation system proved a sustainable weed management strategy in cotton crop. Planta Daninha, 35, e017158976.

14. Harish, J., Rajkumar, B., Pawar, D. D., & Kale, K. D. (2017). Nutrient availability in Btcotton by using drip fertigation under different phosphorous sources. Int. J. Res. Sci. Tech, 6, 406–410.

15. Himanshu, S. K., Ale, S., Bordovsky, J., & Darapuneni, M. (2019). Evaluation of crop-growth-stage-based deficit irrigation strategies for cotton production in the Southern High Plains. Agricultural Water Management, 225, 105782.

16. Hou, X., Fan, J., Hu, W., Zhang, F., Yan, F., Xiao, C., Li, Y., & Cheng, H. (2021). Optimal irrigation amount and nitrogen rate improved seed cotton yield while maintaining fiber quality of drip-fertigated cotton in northwest China. Industrial Crops and Products, 170, 113710.

17. Khan, A., Najeeb, U., Wang, L., Tan, D. K. Y., Yang, G., Munsif, F., Ali, S., & Hafeez, A. (2017). Planting density and sowing date strongly influence growth and lint yield of cotton crops. Field Crops Research, 209, 129–135.

18. Koudahe, K., Sheshukov, A. Y., Aguilar, J., & Djaman, K. (2021). Irrigation-water management and productivity of cotton: A review. Sustainability, 13(18), 10070.

19. Macdonald, B. C. T., Latimer, J. O., Schwenke, G. D., Nachimuthu, G., & Baird, J. C. (2018). The current status of nitrogen fertiliser use efficiency and future research directions for the Australian cotton industry. Journal of Cotton Research, 1(1), 15. https://doi.org/10.1186/s42397-018-0015-9

20. Magare, P. N., Katkar, R. N., & Jadhao, S. D. (2018). Effect of fertigation on yield, quality and soil fertility status under cotton grown in Vertisol. International Journal of Chemical Studies, 6(2), 42–46.

21. Mishra, S. K., Kaur, V., & Singh, K. (2021). Evaluation of DSSAT-CROPGRO-cotton model to simulate phenology, growth, and seed cotton yield in northwestern India. Agronomy Journal, 113(5), 3975–3990. https://doi.org/10.1002/agj2.20788

22. Neelakanth, J. K., Rajkumar, S., Gundlur, S. S., & Dasar, G. V. (2019). Effect of surface and sub-surface drip irrigation system on seed cotton in vertisolsof malaprabha command in northern karnataka. J. Pharmacogn. Phytochem, 8(2), 956–958.

23. O’Shaughnessy, S. A., Colaizzi, P. D., & Bednarz, C. W. (2023). Sensor feedback system enables automated deficit irrigation scheduling for cotton. Frontiers in Plant Science, 14, 1149424.

24. Paramesh, V., Mohan Kumar, R., Rajanna, G. A., Gowda, S., Nath, A. J., Madival, Y., Jinger, D., Bhat, S., & Toraskar, S. (2023). Integrated nutrient management for improving crop yields, soil properties, and reducing greenhouse gas emissions. Frontiers in Sustainable Food Systems, 7, 1173258.

25. Peshin, R., Hansra, B. S., Singh, K., Nanda, R., Sharma, R., Yangsdon, S., & Kumar, R. (2021). Long-term impact of Bt cotton: An empirical evidence from North India. Journal of Cleaner Production, 312, 127575.

26. Prajapati, G. V., & Subbaiah, R. (2018). Combined response of irrigation system regimes and mulching on productivity of Bt. Cotton. J. Agrometeorol, 20, 47–51.

27. Pretty, J., Benton, T. G., Bharucha, Z. P., Dicks, L. V., Flora, C. B., Godfray, H. C. J., Goulson, D., Hartley, S., Lampkin, N., & Morris, C. (2018). Global assessment of agricultural system redesign for sustainable intensification. Nature Sustainability, 1(8), 441–446.

28. Rajpoot, S. K., Rana, D. S., & Choudhary, A. K. (2021). Crop and water productivity, energy auditing, carbon footprints and soil health indicators of Bt-cotton transplanting led system intensification. Journal of Environmental Management, 300, 113732.

29. Singh, K., Brar, A. S., & Singh, H. P. (2018). Drip fertigation improves water and nitrogen use efficiency of Bt cotton. Journal of Soil and Water Conservation, 73(5), 549–557. https://doi.org/10.2489/jswc.73.5.549