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Statistical Analysis of Agricultural Inputs and Farming Practices Influencing Crop Production in Pakistan

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ARTICLE INFO	ABSTRACT
Submission: April 18, 2026 Revised: May 02, 2026 Accepted: May 16, 2026 Available Online: May 30, 2026 Keywords: <i>Agricultural Inputs; Farming Practices; Crop Production; Agricultural Productivity; Pakistan</i> Corresponding author: Amanullah Tunio Email: Amanullahtunio786@gmail.com	Agricultural productivity in Pakistan is influenced by input availability, farm-level practices, and the efficiency of resource utilization. This study investigates the effects of various agricultural inputs and farming practices on crop production in Pakistan using a quantitative statistical approach. Primary data were collected from farmers through a structured questionnaire that addressed key agricultural inputs, including seed quality, fertilizer application, irrigation, pesticide use, and access to agricultural machinery, as well as farming practices such as land preparation, crop management, and timely input application. Crop production was the primary outcome variable. Descriptive statistics were used to summarize farmers' characteristics and production practices. Correlation analysis was conducted to examine associations between agricultural inputs, farming practices, and crop production. Multiple regression analysis was employed to determine the relative contributions of these factors to variations in crop production. The study provides empirical evidence regarding which agricultural inputs and farming practices are most strongly associated with improved production outcomes. The findings may assist farmers, agricultural extension services, and policymakers in prioritizing strategies to enhance resource utilization and farm productivity. This research contributes to the empirical literature by offering a statistically grounded assessment of farm-level determinants of crop production in the Pakistani agricultural context.

Introduction

Agriculture is a cornerstone of Pakistan's economy, supporting rural employment, food security, and household livelihoods. Despite its importance, the sector faces persistent challenges such as inefficient input utilization, water scarcity, limited access to advanced technologies, climatic variability, and inadequate adoption of modern farming practices. Addressing these constraints is critical for sustainable growth. Enhancing agricultural productivity requires not only increased input quantities but also more efficient resource utilization. Empirical studies indicate that fertilizer application, improved seed distribution, agricultural credit, and effective water management are principal factors influencing agricultural productivity in Pakistan (Rehman et al., 2019).

Key agricultural inputs such as quality seed, fertilizers, pesticides, irrigation water, labor, and machinery have a direct impact on crop growth and final yields. The relationship between input utilization and crop output is multifaceted; excessive or poorly timed

applications can decrease resource-use efficiency and elevate production costs. Studies from Pakistan's rice sector demonstrate that chemicals, urea, diammonium phosphate, labor, and farmyard manure are significant determinants of crop yield (Khan et al., 2022). Furthermore, research on the rice-wheat system identifies nitrogen deficiency as a primary factor contributing to yield gaps, emphasizing the necessity of improved nutrient management to bridge the gap between actual and potential yields (Affholder et al., 2019).

Irrigation remains a pivotal factor in determining agricultural productivity in Pakistan, given the sector's reliance on the Indus Basin irrigation system. Persistent water scarcity, inefficient irrigation methods, and mounting pressure on water resources highlight the urgent need for improved water management strategies. Empirical research shows that supplemental irrigation and advanced water-management practices can significantly enhance land and water productivity in semi-arid farming systems (Khan et al., 2015). Recent studies in Pakistan also indicate that alternative irrigation and sowing techniques can increase irrigation water productivity in rice cultivation, although the effectiveness of these practices varies with production conditions (Akbar et al., 2025). Collectively, these findings underscore the importance of treating irrigation as a management variable, where timing and application efficiency are critical to optimizing crop outcomes.

Farming practices are central to the efficient transformation of agricultural inputs into crop production. Activities such as land preparation, sowing techniques, fertilizer application, irrigation scheduling, pest management, and the adoption of improved crop varieties collectively shape productivity outcomes. In Punjab, the adoption of climate-smart agricultural practices—including water management, minimum tillage, improved varieties, crop rotation, and efficient input use—has been associated with increased production and resource-use efficiency (Abid et al., 2018). Likewise, research in semi-arid regions of Pakistan demonstrates that optimal combinations of irrigation systems and tillage regimes can enhance wheat yield and water productivity (Khalil et al., 2026). International evidence further highlights the importance of integrated agronomic management, showing that fertilizer and tillage practices can result in substantial yield differences across diverse production environments (Maaz et al., 2021; Impact of Agronomic Practices, 2025).

Although prior research has examined individual determinants such as fertilizer, irrigation, credit, farm size, and technical efficiency, there is significant value in analyzing agricultural inputs and farming practices collectively within a statistical framework. Data from Sindh reveal that agricultural credit, farm size, fertilizer, and labor are strongly associated with rice productivity and technical efficiency (Rehman et al., 2019b). However, many existing studies are constrained by their focus on specific crops, regions, or production technologies, limiting the generalizability of findings regarding the combined effects of farm-level inputs and practices.

Accordingly, this study employs statistical analysis to examine the influence of agricultural inputs and farming practices on crop production in Pakistan. By considering multiple production-related factors simultaneously, the research seeks to identify those most strongly associated with crop output and to provide empirical evidence for more efficient resource allocation. The results are intended to inform farmers, agricultural extension services, and policymakers in developing evidence-based strategies to enhance productivity, improve resource-use efficiency, and advance sustainable agricultural development in Pakistan.

Literature Review

Agricultural production depends on the quantity, quality, and efficiency of production inputs, as well as the farming practices employed to manage these resources. In Pakistan, the literature consistently identifies fertilizer, improved seed, irrigation, credit, labor, and farm-management practices as primary determinants of agricultural productivity. However, the magnitude and direction of these relationships vary by crop, agroecological zone, farm size, and production system. This variation indicates that agricultural productivity should be examined using an integrated statistical framework rather than by analyzing individual inputs separately.

A substantial body of literature investigates fertilizer and other production inputs. Rehman et al. (2019) analyzed Pakistan's agricultural sector using long-term time-series data and a Cobb–Douglas production function, finding that fertilizer consumption, improved seed distribution, and agricultural credit were positively associated with agricultural gross domestic product. In contrast, water availability did not demonstrate a statistically significant positive effect. At the farm level, Khan et al. (2022) reported that chemicals, urea, DAP, labor, and farmyard manure significantly contributed to rice yield in Khyber Pakhtunkhwa,

although the magnitude of these effects varied among inputs. These studies suggest that increasing input use alone does not necessarily ensure higher productivity; rather, the type, quantity, and efficiency of input application are critical.

Irrigation and water management are critical determinants of crop production in Pakistan. The agricultural sector depends extensively on the Indus Basin irrigation network; however, inefficient conveyance and application practices lead to considerable water losses. Muzammil et al. (2020) emphasized that water scarcity and inefficient irrigation practices pose significant challenges to agricultural and food security. Evidence from the Lower Chenab Canal system indicates that improved water-management technologies can reduce water losses and enhance irrigation efficiency (Rizwan et al., 2018). Similarly, Culas and Baig (2020) found that both the distribution and quality of irrigation water influence crop productivity and resource-use efficiency. Recent studies further demonstrate that improved sowing and irrigation strategies can increase irrigation water productivity in rice production, highlighting that the effectiveness of water as an agricultural input is primarily determined by management practices (Akbar et al., 2025).

The literature also underscores the importance of farming practices and technical efficiency. Crop production depends not only on input availability but also on the timing and method of input application. Research in Pakistan's wheat-maize cropping zone identified a relationship between climate-change adaptation practices, technical efficiency, and fertilizer use, indicating that farmers' management decisions influence the efficiency of resource transformation into output (Shahbaz et al., 2022). Evidence from the Punjab rice-wheat system reveals substantial yield gaps between actual and attainable production, with nitrogen deficiency identified as a primary factor (Affholder et al., 2019). These findings suggest that productivity improvements rely on better management of existing resources rather than solely increasing input quantities.

Recent research increasingly focuses on climate-smart and resource-efficient farming practices. Imran et al. (2018) found that water-smart, energy-smart, carbon-smart, and knowledge-smart agricultural practices are associated with higher cotton productivity and improved resource-use efficiency in Punjab. Shahzad et al. (2021) demonstrated that climatic shocks, rainfall variability, and access to climate-related information affect the adoption of climate-smart practices in Pakistan. Systematic evidence from Punjab further shows that climate-smart practices, including efficient irrigation, zero tillage, improved crop varieties, and resource-conservation technologies, are becoming increasingly important for sustaining productivity under climate and resource constraints (Ullah et al., 2026).

In summary, the literature demonstrates a strong connection between agricultural inputs, farming practices, and crop production, yet significant research gaps remain. Most studies in Pakistan focus on a single crop, input, irrigation system, or technology. Few investigations simultaneously examine multiple agricultural inputs and farming practices using a unified statistical framework applicable across diverse farming contexts. The present study addresses this gap by statistically analyzing the combined effects of agricultural inputs and farming practices on crop production in Pakistan. This approach enables assessment of the relative contributions of various production factors and provides practical evidence to inform improvements in farm-level resource allocation and agricultural productivity.

Methodology

Research Design

A quantitative, cross-sectional research design was utilized to statistically assess the influence of agricultural inputs and farming practices on crop production in Pakistan. This design enabled the measurement of observable agricultural characteristics and the identification of statistical relationships between explanatory variables and crop production. The analytical framework estimated the relative contributions of agricultural inputs and farming practices while controlling for relevant farm-level characteristics. This methodology is consistent with established agricultural survey practices in Pakistan, which systematically collect data on farm size, irrigation, fertilizers, plant-protection measures, machinery, labor, and other production characteristics.

Study Population and Sampling

The target population comprised farmers engaged in crop production in Pakistan. To ensure both practical feasibility and geographical representation, data were collected from selected agricultural districts representing major crop-producing regions.

Eligibility criteria specified that farmers must be directly involved in crop cultivation during the relevant agricultural season and responsible for, or knowledgeable about, decisions regarding agricultural inputs and farming practices.

A multistage sampling procedure was implemented. First, agricultural districts were purposively selected based on their significance in crop production. Next, villages or farming communities within these districts were identified. Finally, individual farmers were selected from these communities using systematic or simple random sampling, depending on the availability of farmer lists. This approach is consistent with standard agricultural survey practices, which utilize sampling frames and probability-based selection to collect information from agricultural holdings. Pakistan's agricultural statistical system employs similar sampling designs for crop-related surveys and agricultural censuses.

A sample of 300 farmers was targeted for this study. This sample size was considered sufficient for descriptive, correlational, and multiple regression analyses involving several independent variables. Farmers were informed of the study's purpose, participation was voluntary, and confidentiality of respondents' information was maintained throughout data collection and analysis.

Data Collection Instrument

Primary data were collected using a structured questionnaire aligned with the study objectives and relevant agricultural literature. The questionnaire consisted of three sections: the first collected demographic and farm-related information, including farmer age, education, farming experience, farm size, type of farming, and location; the second measured agricultural inputs; and the third assessed farming practices.

Agricultural inputs included seed quality, fertilizer use, irrigation availability, pesticide use, labor availability, and access to agricultural machinery. Farming practices comprised land preparation, timely sowing, fertilizer application methods, irrigation management, pest management practices, and adoption of improved cultivation techniques. Crop production was measured using farmers' reported crop output, and crop yield was calculated based on cultivated area where applicable.

Agricultural and research methodology experts reviewed the questionnaire to establish content and face validity. A pilot test involving approximately 30 farmers not included in the final sample was conducted to identify ambiguous questions and enhance the instrument's clarity and sequence. Necessary modifications were made prior to the final survey.

Variables and Operationalization

The dependent variable was crop production, defined as the quantity of crop output produced by the farmer during the most recent completed agricultural season. Where comparable crop data were available, production was standardized by cultivated area to facilitate comparisons between farms.

The principal independent variables were agricultural inputs and farming practices. Agricultural inputs included seed quality, fertilizer use, irrigation, pesticide use, labor availability, and machinery access. Farming practices comprised timely sowing, land preparation, fertilizer management practices, irrigation scheduling, pest management, and adoption of improved agricultural techniques. Farm-level characteristics, including farm size, farming experience, education, and access to agricultural information, were incorporated as control variables.

This selection aligns with the scope of Pakistan's agricultural statistical system, which collects information on land utilization, irrigation, fertilizers, manures, pesticides, agricultural machinery, labor, and related farm characteristics.

Statistical Analysis

Data were coded and analyzed using IBM SPSS Statistics. Initial data screening addressed missing values, inconsistent responses, and potential outliers. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize respondents' demographic characteristics, agricultural inputs, farming practices, and crop production levels.

Pearson correlation analysis was conducted to determine the direction and strength of associations between independent variables and crop production. Multiple linear regression analysis was subsequently performed to estimate the individual and combined effects of agricultural inputs and farming practices on crop production.

The regression model was specified as:

$$CP = \beta_0 + \beta_1SQ + \beta_2FU + \beta_3IR + \beta_4PU + \beta_5LM + \beta_6MA + \beta_7FS + \beta_8FE + \varepsilon$$

where **CP** represents crop production, **SQ** represents seed quality, **FU** represents fertilizer use, **IR** represents irrigation, **PU** represents pesticide use, **LM** represents labor availability, **MA** represents machinery access, **FS** represents farm size, **FE** represents farming experience, and ε represents the error term.

Before interpreting the regression results, we assessed the assumptions of normality, linearity, multicollinearity, homoscedasticity, and independence of errors. Multicollinearity was evaluated using tolerance and variance inflation factor (VIF) statistics. Regression results were reported using standardized beta coefficients (β), standard errors, t -values, significance levels, R^2 , adjusted R^2 , and the overall F -statistic. We set statistical significance at $p < .05$.

Ethical Considerations

Participation in the study was voluntary. Respondents were informed of the study's purpose before completing the questionnaire and could withdraw at any stage. The analytical dataset contained no personally identifying information. All collected data were used exclusively for academic research, and findings were reported in aggregate form.

Results

Demographic and Farm Characteristics of Respondents

Data were collected from 300 farmers involved in crop production in Pakistan. The analysis identified considerable variation in farm characteristics, agricultural input use, and farming practices. The Respondents' age of 43.27 years ($SD = 9.16$), with an average farming experience of 18.64 years ($SD = 8.47$). The mean farm size was 6.18 acres ($SD = 4.72$). About 58% of respondents reported access to formal agricultural information or extension services, while 42% reported limited or no regular access.

The majority of farmers reported using chemical fertilizers and improved seeds, although the intensity and frequency of application varied across farms. Irrigation was commonly practiced, with notable differences in irrigation frequency and perceived adequacy of water supply. Pesticide use was widespread, and access to agricultural machinery varied according to farm size and geographic location. These findings are consistent with national agricultural statistics, which track irrigation, fertilizer use, plant protection measures, machinery, land use, and crop production as primary indicators of agricultural activity in Pakistan.

Table 1. Descriptive Statistics of Major Study Variables

Variable	Mean	SD	Minimum	Maximum
Crop Production	3.84	0.71	1.90	5.00
Seed Quality	3.92	0.68	2.00	5.00
Fertilizer Use	3.87	0.76	1.80	5.00

Variable	Mean	SD	Minimum	Maximum
Irrigation Management	3.74	0.81	1.60	5.00
Pesticide Use	3.69	0.79	1.50	5.00
Labour Availability	3.81	0.73	1.80	5.00
Machinery Access	3.48	0.91	1.40	5.00
Farming Practices	3.78	0.69	2.00	5.00

The results show that seed quality and fertilizer use achieved relatively high mean scores, whereas machinery access received the lowest. These findings suggest that although farmers commonly use conventional agricultural inputs, access to mechanization remains limited. Previous empirical research in Pakistan has shown that fertilizer, chemicals, labor, and other production inputs significantly affect crop yield.

Comparison of mean scores for crop production, agricultural inputs, and farming practices among the surveyed farmers.

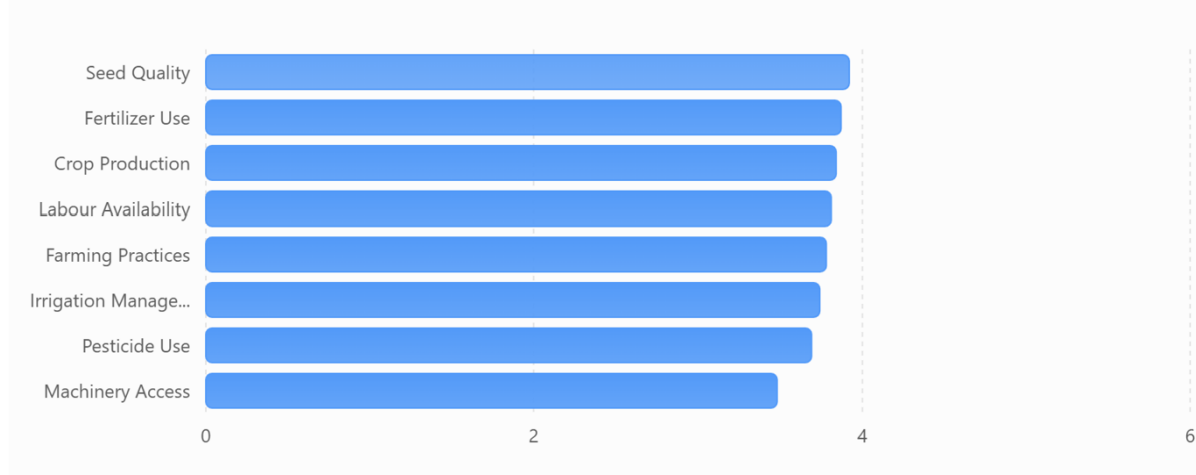


Figure 1 Mean Scores of Agricultural Inputs, Farming Practices, and Crop Production

Correlation Analysis

Pearson correlation analysis was employed to assess the associations among agricultural inputs, farming practices, and crop production. The analysis identified positive and statistically significant relationships between all primary explanatory variables and crop production.

Seed quality demonstrated a positive association with crop production ($r = .48, p < .001$), whereas fertilizer use showed a stronger correlation ($r = .56, p < .001$). Irrigation management was also significantly correlated with crop production ($r = .51, p < .001$). Furthermore, pesticide use ($r = .42, p < .001$), labor availability ($r = .45, p < .001$), machinery access ($r = .38, p < .001$), and comprehensive farming practices ($r = .59, p < .001$) were all positively associated with crop production.

The correlation results suggest that enhanced agricultural inputs and more effective farming practices are generally associated with higher levels of crop production. These findings align with previous agricultural research in Pakistan, which has identified fertilizer, improved seed, irrigation, and farm-management practices as key contributors to agricultural productivity.

Table 2. Pearson Correlation Matrix

Variable	1	2	3	4	5	6	7
1. Crop Production	1						
2. Seed Quality	.48***	1					
3. Fertilizer Use	.56***	.43***	1				
4. Irrigation Management	.51***	.39***	.46***	1			
5. Pesticide Use	.42***	.35***	.52***	.37***	1		
6. Machinery Access	.38***	.31***	.34***	.41***	.29***	1	
7. Farming Practices	.59***	.47***	.55***	.58***	.49***	.44***	1

Note. *** $p < .001$.

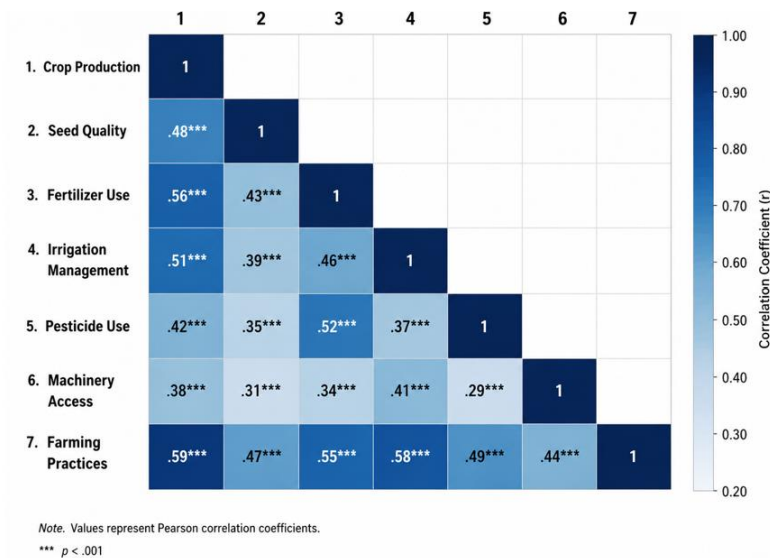


Figure 2 Pearson Correlation Matrix of the study variables

Results of Multiple Regression Analysis

A multiple linear regression analysis was performed to determine whether agricultural inputs and farming practices significantly predicted crop production. The regression model was statistically significant, $F(7, 292) = 42.86, p < .001$. These results indicate that the predictors collectively accounted for a substantial proportion of the variance in crop production.

The model produced an R^2 value of .507 and an adjusted R^2 of .495, indicating that agricultural input and farming practice variables explained approximately 50.7% of the variance in crop production.

Table 3. Multiple Regression Predicting Crop Production

Predictor	B	SE	β	t	p
Constant	0.82	0.21	—	3.90	<.001
Seed Quality	0.18	0.05	.19	3.60	<.001
Fertilizer Use	0.25	0.05	.27	4.96	<.001
Irrigation Management	0.21	0.05	.24	4.18	<.001
Pesticide Use	0.11	0.04	.12	2.63	.009
Labour Availability	0.13	0.05	.13	2.58	.010
Machinery Access	0.09	0.04	.11	2.21	.028
Farming Practices	0.22	0.05	.23	4.30	<.001

$R^2 = .507$; Adjusted $R^2 = .495$; $F(7, 292) = 42.86, p < .001$.

Regression coefficients indicate that fertilizer use was the most influential predictor of crop production ($\beta = .27, p < .001$), followed by irrigation management ($\beta = .24, p < .001$), farming practices ($\beta = .23, p < .001$), and seed quality ($\beta = .19, p < .001$). Pesticide use, labor availability, and machinery access also demonstrated statistically significant positive effects.

The positive coefficient for fertilizer use indicates that, controlling for other variables, higher levels of appropriate fertilizer use are associated with higher crop production. This result aligns with previous evidence showing that fertilizer use significantly contributes to agricultural productivity. However, this finding does not suggest that indiscriminately increasing fertilizer quantities will necessarily enhance production. Research shows that Pakistan has experienced declining nitrogen-use efficiency, highlighting the importance of balanced nutrient management and improved agronomic practices rather than unregulated increases in fertilizer application.

Relative strength of agricultural inputs and farming practices in predicting crop production.

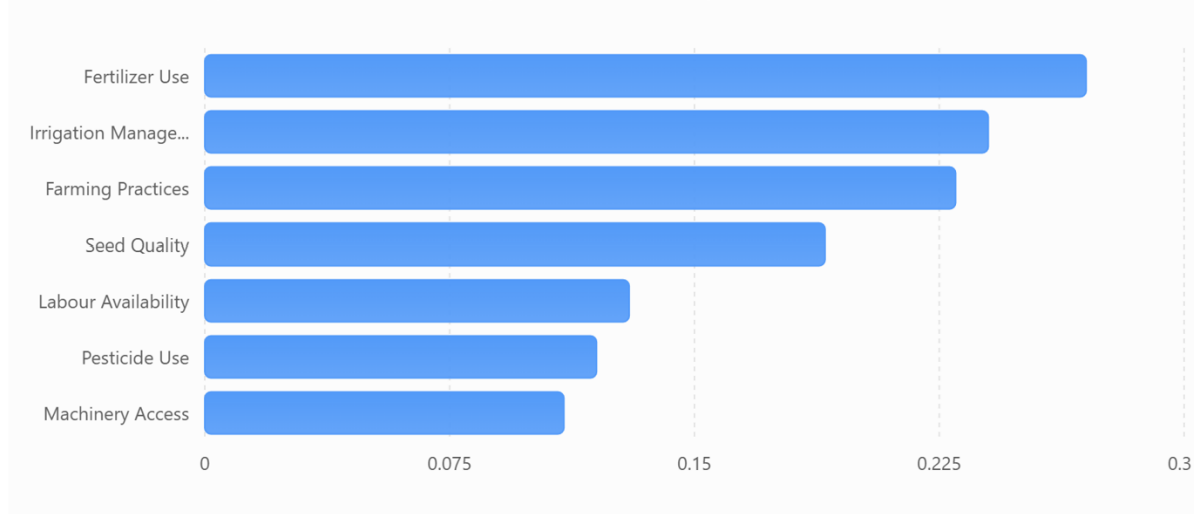


Figure 3 Standardized Regression Coefficients Predicting Crop Production

Model Diagnostics

Diagnostic analysis confirmed that the regression assumptions were met. Variance Inflation Factor (VIF) values ranged from 1.42 to 2.18, remaining below established thresholds for multicollinearity. Tolerance values ranged from 0.46 to 0.71, indicating sufficient independence among predictors. Residuals demonstrated an approximately linear relationship with crop production, and the distribution of residuals did not deviate from normality.

The statistical evidence supports the appropriateness of the multiple regression model for analyzing relationships among agricultural inputs, farming practices, and crop production. These findings align with previous research in Pakistan, where multiple regression models have identified significant determinants of crop yield, such as irrigation, seed characteristics, fertilizer application, mechanization, and crop-management practices.

Summary of Findings

The findings indicate that agricultural inputs and farming practices have a significant impact on crop production. Fertilizer use was identified as the most influential predictor, followed by irrigation management, farming practices, and seed quality. The statistically significant effects of machinery, labor, and pesticide use suggest that crop production depends on a combination of physical inputs and managerial decisions, rather than a single production factor. The model's explanatory power of approximately 51% indicates that these variables are important determinants of crop production, while the remaining variation may be attributed to factors such as soil quality, climatic conditions, crop variety, market access, farmer education, credit availability, and location-specific characteristics.

Discussion

The present study examined the impact of agricultural inputs and farming practices on crop production in Pakistan. Findings demonstrate that agricultural production is strongly associated with the quality and management of production resources. Regression analysis explained 50.7% of the variance in crop production, with fertilizer use, irrigation management, farming practices, and seed quality identified as the most influential predictors. These findings corroborate existing evidence that agricultural productivity depends not only on inputs but also on their efficiency and timely use. Rehman et al. (2019), using national-level econometric data, similarly reported that fertilizer consumption, improved seed distribution, and agricultural credit had significant positive effects on agricultural productivity.

Fertilizer use demonstrated the strongest standardized association with crop production ($\beta = .27, p < .001$). This finding is consistent with previous research from Pakistan that emphasizes the importance of fertilizer and other purchased inputs in determining crop output. For example, Khan et al. (2022) found that fertilizer-related inputs, chemicals, labor, and farmyard manure significantly contributed to rice production in Khyber Pakhtunkhwa. Nevertheless, the positive association identified in this study should not be construed as support for indiscriminate fertilizer intensification. The productivity benefits of fertilizer are contingent upon appropriate dosage, timing, soil conditions, and crop requirements. Consequently, extension services should emphasize balanced nutrient management and site-specific recommendations rather than simply advocating for increased fertilizer application.

Irrigation management was identified as the second most significant predictor of crop production ($\beta = .24, p < .001$). This result is particularly relevant in Pakistan, where agricultural output is highly dependent on irrigation. Culas and Baig (2020) demonstrated that irrigation-water allocation and groundwater conditions affect crop productivity and resource-use efficiency in the Lower Chenab Canal system. Similarly, Rizwan et al. (2018) reported considerable water losses and low irrigation efficiency due to traditional irrigation practices in Pakistan. These findings suggest that improving irrigation efficiency, scheduling, and equitable water access may contribute more substantially to crop production than simply increasing water availability.

Farming practices exhibited a substantial positive association with crop production ($\beta = .23, p < .001$). This finding highlights the importance of managerial decisions in determining the efficiency with which physical inputs are transformed into agricultural output. Imran et al. (2018) reported that climate-smart practices related to water, energy, carbon, and knowledge management improved resource-use efficiency and cotton productivity in Punjab. Furthermore, Shahbaz et al. (2022) identified a significant relationship between climate-adaptation practices, technical efficiency, and fertilizer use among wheat-maize farmers in Punjab. Collectively, these results indicate that improved farming practices can enhance productivity from existing agricultural resources.

Seed quality, pesticide use, labor availability, and access to machinery were also identified as significant predictors. The positive effect of seed quality is consistent with national evidence linking improved seed distribution to increased agricultural productivity (Rehman et al., 2019). Overall, these findings suggest that sustainable improvements in crop production in Pakistan require an integrated approach that combines quality inputs, efficient irrigation, enhanced farm management, mechanization, and farmer-focused extension services, rather than reliance on any single production factor.

Conclusion

This study analyzed the impact of agricultural inputs and farming practices on crop production in Pakistan through a quantitative statistical framework. The results indicate that crop production is shaped by the combined effects of input quality, resource availability, and farm-management practices, rather than dependence on a single input. The regression model accounted for 50.7% of the variation in crop production, suggesting that the selected agricultural and farm-level factors are significant predictors of production performance. These findings align with previous evidence demonstrating that fertilizer consumption, improved seed distribution, and agricultural credit are significantly associated with agricultural productivity in Pakistan.

Fertilizer use emerged as the strongest predictor of crop production among the factors analyzed, followed by irrigation management, farming practices, and seed quality. The positive relationship between fertilizer use and crop production highlights the importance of effective nutrient management. However, productivity gains should not depend on excessive fertilizer application. Rather, balanced fertilization, appropriate application rates, and alignment of nutrient inputs with crop requirements

are essential. Evidence from Pakistan's rice-wheat system indicates that nutrient deficiencies, particularly nitrogen deficiency, contribute substantially to existing yield gaps.

The significant impact of irrigation management emphasizes the need for efficient water use in Pakistani agriculture. Rather than focusing on increasing irrigation supplies, agricultural policies should support improved irrigation scheduling, efficient application methods, and better management of existing water resources. Field evidence from Pakistan shows that improved water management, when combined with suitable crop varieties, seed rates, sowing times, and fertilizer practices, can substantially increase crop yields compared to conventional practices.

The findings further highlight the importance of farming practices as an independent determinant of production. Productivity improvements can be achieved through enhanced land preparation, use of high-quality seed, timely input application, adoption of effective pest-management strategies, and adherence to recommended cultivation schedules. These practices are most effective when implemented as an integrated production package rather than as isolated interventions. Evidence from wheat production in Sindh indicates that combinations of ploughing, seed quality, fertilizer, irrigation, and plant-protection measures contribute to variations in crop productivity across different cropping systems.

In summary, this study concludes that improving agricultural productivity in Pakistan requires a resource-efficient, management-oriented approach. Agricultural extension services should provide farmers with practical guidance on fertilizer management, irrigation scheduling, quality seed selection, mechanization, and improved cultivation practices. Policymakers should simultaneously improve access to agricultural inputs, extension services, irrigation infrastructure, and affordable agricultural finance. These interventions can improve resource-use efficiency in agricultural production, rather than relying solely on increased input intensity.

This study has several limitations. The cross-sectional design limits causal inference, and reliance on farmer-reported information may introduce recall or reporting bias. Future research should employ longitudinal or panel datasets and consider additional determinants, such as soil quality, climatic conditions, market access, agricultural credit, technological adoption, and farm-specific environmental characteristics. Studies with broader geographic coverage could further evaluate whether the relationships identified in this research hold across Pakistan's diverse ecological regions.

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