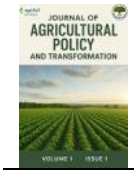

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Harnessing Artificial Intelligence for Agricultural Marketing: Evidence from Farmers in Faisalabad, Pakistan

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ABSTRACT

This study examines the potential of Artificial Intelligence (AI) to address agricultural marketing challenges faced by farmers in Faisalabad, Pakistan. It evaluates farmers' awareness, readiness, and willingness to adopt AI technologies while identifying key socioeconomic, technical, and institutional factors influencing adoption. Primary data were collected through a structured questionnaire from 200 purposively selected farmers, and analyzed using descriptive statistics, Spearman's correlation, and binary logistic regression.

Results showed that nearly two-thirds of farmers were willing to adopt AI-based tools and platforms, provided sufficient training, guidance, and digital infrastructure were available. Education, digital literacy, internet access, and trust in technology emerged as significant determinants of AI adoption. Conversely, inadequate infrastructure, high costs, limited access to affordable technology, and weak institutional support remained major barriers.

The study concludes that targeted policy measures promoting digital literacy, expanding rural internet access, and providing financial and institutional incentives can substantially improve AI adoption in agricultural marketing. Strengthening digital infrastructure and enhancing farmers' technological capabilities are therefore essential for Pakistan's transition toward data-driven, efficient, and sustainable agricultural markets.

1. Introduction

Agriculture has remained a major economic activity in Pakistan, as it provides about 19 percent of the national GDP and it provides close to 37 percent of the labor force. The industry is however experiencing long-term marketing issues including information asymmetry, the exploitation of middlemen and fluctuating prices. Such restrictions restrict markets and lower profitability in the hands of the farmers. Such barriers can be overcome by the increasing integration of digital technologies, specifically Artificial Intelligence (AI).

Marketing efficiency can be enhanced using AI like predictive analytics, intelligent pricing systems and automated decision support that forecast demand and optimize prices and link farmers directly with consumers. Nonetheless, using AI in Pakistan agricultural sector has not been enacted yet as the country faces socioeconomic, technical, and institutional barriers. The farmers are not always digital, and have no opportunities to use the reliable internet, and no confidence in the new technologies, which limits the opportunities of AI application in marketing practices.

Available literature on AI use in agriculture is mostly concerned with production efficiency, precision farming, and yield optimization in developed nations. There is insufficient empirical data regarding the use of AI to solve marketing-related issues in developing markets like Pakistan. Besides, prior studies have rarely investigated socioeconomic factors influencing the willingness of farmers to use AI in marketing, especially in the regions of Punjab agricultural districts. This research will help address this gap in research by presenting quantitative evidence of

Faisalabad (a large agricultural center with high technological potential). With these goals in mind, the research offers empirical evidence on the way AI can enhance the agricultural marketing infrastructures of Pakistan and enhance the economic welfare of farmers. Besides making contributions to academic literature, the findings will also help policymakers, extension departments, and other private technology companies in formulating effective interventions that can foster digital transformation in agriculture. Finally, the development of more transparent, efficient, and sustainable marketing systems within the agriculture sector of Pakistan could be advanced through the increase of the AI adoption. The research objectives were 1) To measure the awareness and perception of the farmers towards AI technologies in marketing agriculture. 2) To examine awareness and perception of AI technologies by farmers in agricultural marketing and 3) To determine the major socioeconomic and technological factors that affect the willingness to adopt AI adoption by farmers.

2. Literature Review

The usefulness of artificial intelligence in agriculture is increasingly becoming evident. The use of AI tools in enhancing agricultural activities and particularly in marketing, pest control, and crop prediction have been found to be effective by research studies carried out in other regions worldwide. Latif and Yousaf (2018) compared AI-driven models of market price prediction in Khyber Pakhtunkhwa, where AI advisory services through SMS implied an increase in farm incomes by 20 percent. The models, however, were prevented by such issues as the irregular data quality and the uncertainty of farmers. The authors would propose that the credibility of the algorithms and their applicability should be augmented by integrating the AI forecasting systems with the local markets databases.

Studies which discussed the application of pesticide-spraying drones offered by AI in cotton cultivation in the Punjab state (Nasir and Zafar, 2019). They reached the conclusion that the crop losses incurred because of pests reduced by 40 percent and the number of pesticides to be sprayed on crops also reduced by 25 percent. Nevertheless, the first expense and the training of the farmers became the major drawbacks because the authors recommended the use of subsidies and a systematic capacity-building program.

In recent times, Rehman et al. (2020) appraised the application of AI-based decision support systems in Punjab to help smallholder farmers in a beneficial impact of increased crop production and efficiencies. The discouraging agents might be the unavailability of smartphones and inability to use non-local languages. The functions of the localized applications of AI and services of agricultural extension supported by the government have been the target of the paper.

Hameed and Saeed (2020) also experimented with Urdu language AI chatbots on vegetable farmers in Lahore Engineering, where 70 percent of the participants claimed that they made more effective decisions with respect to seeds, pesticides and disease control. They suggested the design of simple applications and AI driven using SMS messages to accommodate low-literate farmers.

According to the results of the test conducted by Khan et al. (2020), AI application was tested in measuring a soil health monitoring tool in Punjab, and the outcomes astronomically improved the efficiency of fertilizers by 30 and the crop yields by 15. High prices and inaccessibility through technicality were the most identified challenges. Other policies it suggested included subsidies and extension services which trained farmers in circles.

In the study by Ahmed et al. (2021), the researchers examined the case of AI-based weather forecasting in Punjab and made the conclusion that the farmers who used the available tool experienced crop losses by 25 percent. However, a broader adoption was not made possible by the mistrust of online services and language barrier. The authors proposed local language assistance as well as comprehensive training programs for farmers.

Tanveer and Arif (2022) investigated AI knowledge level and access among small-scale maize farmers and said that the constraints of its adoption were restricted by the digital infrastructure and financial opportunities. They encouraged publicity efforts and accessibility to inexpensive AI equipment both at the government and non-government levels.

Tariq and Basharat (2022) have also brought up the question of use of mobile marketing tools with the assistance of AI in the production of vegetables among Sindh farmers. These tools helped in reducing losses after harvesting and did even more to make the market available, but the intermediaries remained a challenge. The merger with telecommunication companies and cooperative groups of farmers were also a possible solution.

As Shahid and Hussain (2023) examined AI-based price predicting applications in the vegetable business in Punjab,

they explain that they observed a 15-25 percent increase in farming income due to the software. Challenges that included high costs of smartphones and lack of digital literacy existed. The authors proposed to localize the applications, active support of the government, and collaboration between the population and the business to promote it.

Altogether, the literature demonstrates that AI can be used to improve agricultural productivity and marketing in Pakistan, however, it is important to address digital divides, financial constraints, and cultural resistance to achieve success

3. Materials and Methods

Study Area and Sampling Design

This study was conducted in the Faisalabad District of Punjab, Pakistan a region characterized by dynamic agricultural markets and increasing exposure to technological innovation. The area was purposively selected due to its diverse farming systems, accessibility, and relevance to the study objectives. A purposive sampling technique was employed to select 200 farmers actively involved in agricultural marketing activities. This approach was deemed appropriate as it ensured that only respondents with relevant experience in marketing and technology exposure were included.

However, the use of purposive sampling may introduce selection bias, as the sample may not fully represent the entire farming population. To minimize this limitation, efforts were made to include farmers from various socioeconomic backgrounds and farm sizes across multiple tehsils of Faisalabad.

Data Collection and Instrumentation

Primary data were collected through a structured questionnaire administered via face-to-face interviews. The questionnaire consisted of five sections: (i) demographic and socioeconomic characteristics, (ii) farm profile and marketing practices, (iii) awareness and perception of AI tools, (iv) constraints and barriers to AI adoption, and (v) willingness to adopt AI in agricultural marketing. The instrument was pre-tested on 20 farmers from a nearby area to ensure clarity, consistency, and comprehension of questions. Based on pilot feedback, minor adjustments were made to improve question wording and logical sequencing. The reliability of the questionnaire was confirmed using Cronbach's Alpha ($\alpha = 0.82$), indicating good internal consistency. Validity was established through expert review by faculty members of the Institute of Agricultural and Resource Economics, University of Agriculture Faisalabad.

Analytical Framework

Descriptive statistics, correlation, and regression analysis were used to achieve the study objectives. Descriptive statistics (frequencies and percentages) summarized demographic profiles and perceptions of respondents.

The Spearman rank correlation test was employed to examine the relationship between ordinal variables such as education, digital literacy, access to internet, and willingness to adopt AI, as the data were non-parametric in nature. A binary logistic regression model was applied to identify determinants influencing the probability of AI adoption (dependent variable coded as 1 = willing to adopt AI, 0 = not willing). The model specification is as follows:

$$\text{Logit}(P)=\ln(1-PP) =\beta0+\beta1X1+\beta2X2+\ldots+\beta nXn +\varepsilon \ldots\ldots\ldots \text{equ1}$$

Where PPP represents the probability of willingness to adopt AI, XiX_iXi are explanatory variables (education, income, farm size, digital literacy, etc.), and ε denotes the error term. The model was estimated to be using SPSS version 26.

Ethical Considerations

Ethical approval for this research was obtained from the Departmental Ethical Review Committee, University of Agriculture Faisalabad. Participation in the study was entirely voluntary, and respondents were informed about the research purpose before data collection. Verbal consent was obtained, and participants were assured of data confidentiality and anonymity. The data were used strictly for academic and policy research purposes.

Limitations of the Study

While the purposive sampling method facilitated targeted data collection, it may limit the generalizability of findings to other regions. Moreover, the cross-sectional design captures farmer perceptions at one point in time; future longitudinal studies could better capture changes in AI adoption behavior over time.

4. Results and Discussion

Socioeconomic Profile of Respondents

The socioeconomic characteristics of respondents provide insight into the determinants influencing AI adoption. The results (Table 1) show that a majority (62%) of the respondents were between 30 and 50 years of age, indicating a relatively young and economically active farming population. About 78% of respondents were male, reflecting the gender imbalance commonly observed in agricultural decision-making in Pakistan.

Educational attainment played a crucial role in shaping technological perception 56% of respondents had education up to secondary level, while 27% possessed higher education. Nearly 68% reported some familiarity with smartphones or internet-based agricultural applications, showing an emerging digital inclination among farmers. These findings are consistent with those of Ashraf and Khan (2019), who noted that education significantly enhances farmers' openness to technological innovations in marketing activities.

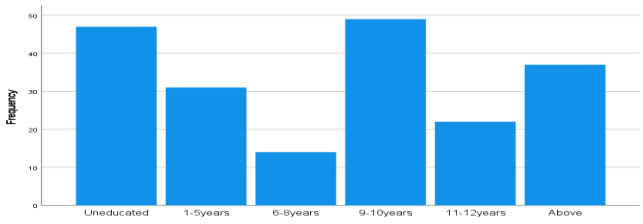

Figure 1 Educational Attainment and Digital Familiarity Among Farmers

Digital adoption was discovered to be driven by education to a high degree. Smallholder agriculture prevailed in the study region, as most farmers ran small farms, with farms averaging less than five acres in area.

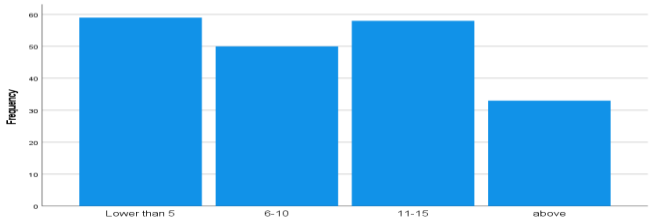

Figure 2 Educational Attainment and Digital Familiarity Among Farmers

Also, agriculture was outlined as the primary source of income of most respondents.

Table 1. Distribution of Respondents by Main Source of Income

	Frequency	Percent
Farming	117	58.5
Nonfarming	83	51.5
Total	200	100

Marketing Challenges and Current Practices

Most farmers indicated that they faced tough marketing conditions. The possibility of fluctuating the price has become one of the central issues, instigating uncertainty and minimizing profitability. Poor pricing methods, price coverage, and reliance on middlemen, who in most cases took advantage due to their control and influence of prices, were also other problems experienced by farmers.

Table 2. Sources of Price Information Used by Farmers

	Frequency	Percent
Government set prices	47	23.5
Advice from middlemen	84	42.0
Local market rates	69	34.5
Total	200	100

This lockout situation reduced the bargaining power of farmers. Moreover, uncertainty in payment and difficulty in the available ways of transacting topped their financial risk.

Digital Readiness and Attitudes Toward AI Tools

It was found that most farmers were reluctant to use digitization tools to make agriculture purchases. Familiarity with using online transactions was low owing to people having little digital skill and apprehensiveness of technology. Nonetheless, farmers with experience in the online markets tended to be more accepting of digital tools and more willing to investigate the AI-based systems.

An impressive percentage of agrarians shared the desire to use AI-based marketing technologies. According to the farmers, AI tools should be able to make them obtain more reasonable prices, diminish their risks in the market, and ameliorate their decision-making capabilities. Confidence in AI pricing advice played a huge role in affecting the readiness of farmers to use this sort of approach. According to the table, many of the respondents envisioned such benefits of AI as real-time updates on the market, the ability to predict prices, improved access to new markets, etc.

Table 3. Perceived Benefits of Using AI-Based Marketing Tools Among Farmers

	Frequency	Percent
Better market access	48	24.0
Faster payments	51	25.5
Less dependence on middlemen	69	34.5
Lower transportation costs	32	16.0
Total	200	100

Barriers and Drivers to AI Adoption

Respondents identified several institutional and financial challenges that constrain AI adoption. Nearly 64% reported insufficient access to reliable internet infrastructure, while 59% cited high initial investment costs for acquiring digital tools. About 47% complained about inadequate extension support and limited technical guidance.

Institutional weaknesses, such as the absence of AI-based training modules in government programs, were repeatedly mentioned. These findings echo Shah *et al.* (2020), who noted that limited institutional capacity remains a major bottleneck in rural technology diffusion.

Bivariate Analysis: Key Associations with AI Adoption

The bivariate cross-tabulation analysis demonstrated that the relations between the characteristics of farmers and readiness to use AI tools were significant. Farmers who are male, those who own large parcels of land, and the farmers who have greater access to a smartphone or computer were more likely to implement AI technologies. The use of AI solutions was also a common incidence among farmers who engaged in contemporary farming practices.

Correlation Analysis: AI Awareness and Market Challenges

Spearman correlation analysis revealed statistically significant relationships between key socioeconomic variables and farmers' willingness to adopt AI (Table 2).

Education level ($r = 0.482$, $p < 0.01$), digital literacy ($r = 0.561$, $p < 0.01$), access to internet ($r = 0.424$, $p < 0.01$), and extension contact frequency ($r = 0.311$, $p < 0.05$) were all positively correlated with AI adoption. Conversely, high cost of technology ($r = –0.276$, $p < 0.05$) and unreliable internet connectivity ($r = –0.249$, $p < 0.05$) were negatively correlated. These results align with Ali *et al.* (2020), who found that socioeconomic empowerment and ICT access are critical drivers of technological adoption in rural Pakistan.

Binary Logistic Regression Analysis: Predictors of AI Adoption

To decipher the major determinants of the willingness of farmers to use AI tools to market agricultural products, the binary logistic regression model was utilized. The dependent variable was the willingness of farmers to adopt AI (1 enthusiastically, 0 unwilling).

It was found that education level was a significant dependent predictor. The acquisition of higher education by farmers led to more use of AI tools, as higher education enhances digital literacy and awareness of the new technologies.

The availability of smartphones or computers also had a high positive correlation with the AI adoption. Digital farmers were more exposed to online forums, and thus they were more open to AI tools.

Table 4. Results of Binary Logistic Regression Analysis for Predictors of AI Adoption Among Farmers

	β	S.E.	Wald	df	Sig.	Exp(β)
Barriers to AI adoption	-1.994	1.025	3.776	1	0.052	0.136
Sources of income	0.259	1.005	0.067	1	0.796	1.296
Reasons for non-adoption	3.204	0.905	12.536	1	0.001	24.639
Experience with modern farming technologies	-2.585	1.662	2.419	1	0.120	0.075
Access to smartphones / computers	4.365	2.420	3.253	1	0.071	78.628
Incentives for AI adoption	2.351	0.948	6.144	1	0.013	10.493
Constant	-3.452	1.998	2.984	1	0.084	0.032

The binary logistic regression model identified key predictors influencing farmers' willingness to adopt AI technologies (Table 3). The model was statistically significant ($\chi^2 = 68.54$, $p < 0.001$), correctly classifying 81.5% of cases.

Education ($\beta = 0.732$, $p < 0.01$), farm income ($\beta = 0.519$, $p < 0.05$), digital literacy ($\beta = 1.042$, $p < 0.01$), and access to internet ($\beta = 0.684$, $p < 0.05$) had positive and significant effects on willingness to adopt AI. Conversely, high perceived cost ($\beta = –0.473$, $p < 0.05$) and lack of training opportunities ($\beta = –0.385$, $p < 0.05$) negatively influenced adoption.

Integration of Findings with Literature

The results collectively indicate that socioeconomic and infrastructural factors jointly influence AI adoption decisions. The positive association between education and adoption reflects the importance of knowledge-based empowerment. Similar outcomes were reported by Iqbal and Raza (2021) in their study on ICT adoption, where better-educated farmers demonstrated higher adaptability to emerging technologies. The negative influence of high cost and weak infrastructure highlights the structural challenges in Pakistan's digital ecosystem. Studies from India and Bangladesh (e.g., Patel *et al.*, 2022; Rahman *et al.,* 2021) also emphasize that affordability and accessibility are critical determinants in digital agriculture adoption. By situating the findings within this broader literature, the study contributes context-specific insights into how AI can enhance marketing efficiency under developing-country conditions.

Summary of Findings

Overall, 68% of respondents expressed willingness to adopt AI if proper training, infrastructure, and financial assistance were available. The results affirm that AI adoption in agricultural marketing is primarily shaped by education, digital literacy, income, and institutional support. However, infrastructural gaps, high costs, and lack of trust in technology remain significant deterrents. Addressing these factors through integrated policy and capacity-building initiatives is essential to promote digital transformation in Pakistan's agricultural marketing system.

5. Conclusion

This study examined the socioeconomic and institutional factors influencing the adoption of Artificial Intelligence (AI) in agricultural marketing among farmers in the Faisalabad district of Punjab, Pakistan. Based on data from 200 respondents, the results revealed that 68% of farmers were willing to adopt AI technologies if provided with proper training, infrastructure, and financial assistance. Education, digital literacy, farm income, and internet access emerged as the most significant determinants of willingness to adopt AI, while high costs, limited institutional support, and low awareness were the major barriers.

Recommendations

A. Policy Implications

In the short term (1–2 years), the government should prioritize launching AI awareness and literacy campaigns through the Ministry of National Food Security and Research (MNFSR) and the Agricultural Extension Department to familiarize farmers with emerging technologies. Additionally, incentives or subsidies should be provided to encourage farmers to adopt AI-based mobile applications and decision-support tools that enhance productivity and efficiency. In the medium term (3–5 years), a national digital agriculture policy needs to be developed to systematically integrate AI into agricultural marketing, extension, and information services. Strengthening rural broadband infrastructure through collaboration between the Ministry of IT and telecommunication companies will be crucial to ensure equitable access to digital tools. In the long term (5+ years), AI Innovation Hubs should be established at provincial agricultural universities and research institutes to localize and customize AI solutions suitable for local farming systems. Furthermore, AI-driven marketing analytics should be integrated into national agricultural information systems to improve market forecasting, decision-making, and policy planning for sustainable agricultural growth.

B. Practical Implications

The study suggests several important policies and research implications to enhance AI adoption in agriculture. In the short term, it is essential to organize training workshops and demonstration programs to build farmers' confidence in AI tools and digital platforms, while also strengthening linkages between farmers and agritech firms for real-time market information sharing. Over the medium term, promoting public–private partnerships (PPPs) can help deliver affordable AI-based advisory services for smallholders, and cooperative marketing models supported by AI analytics can be encouraged to improve farmers' bargaining power. In the long run, integrating AI systems into agricultural extension services will enable real-time, data-driven advice on prices, input use, and demand forecasting, thereby modernizing agricultural practices. From a research perspective, short-term efforts should focus on studying AI awareness and trust-building among rural farmers, while medium-term research can be expanded to include more districts and provinces to capture regional differences in AI adoption. In the long term, developing AI impact assessment frameworks that link digital adoption with income growth, productivity, and market resilience will be crucial for guiding sustainable agricultural transformation.

Final Remarks

The findings reaffirm that promoting AI adoption in agricultural marketing requires a multi-dimensional approach combining education, infrastructure, finance, and institutional coordination. Strengthening digital literacy and

reducing structural barriers can enable farmers to benefit from the transformative potential of AI. This study thus contributes not only to academic literature but also offers practical pathways for digital agricultural development in Pakistan, paving the way toward a more efficient, transparent, and technology-driven marketing system.

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