www.sasinsights.com
SCIENCE AND SOCIETY INSIGHTS
Sci Soc Insights (2025), 1(3): 147-155 Research Article

The Impact of Water Scarcity, Technological Adoption, and Economic Shocks on Food Security of Rural Households in Punjab, Pakistan

Syed Muhammad Taha Hussaini[1], Syed Ali Akbar[2], Syed Ali Ummar[1] and Bilal Aslam[3]

[1]Department of Agricultural and Resource Economics, University of Agriculture Faisalabad, Punjab, Pakistan
[2]University of North America, USA
[3]School of Integrated Social Sciences (SISS), The University of Lahore (UOL), Lahore, Pakistan
*Corresponding author: bilal.aslam@siss.uol.edu.pk

Article History: 25-308	Received: 08 Nov 2024	Revised: 08 Feb 2025	Accepted: 08 Feb 2025	Published Online: 2025

Citation: Aslam B, 2025. The Impact of Water Scarcity, Technological Adoption, and Economic Shocks on Food Security of Rural Households in Punjab, Pakistan. Sci Soc Insights. 1(3): 147-155.

ABSTRACT

The present paper examined the influence of water shortage, uptake of technologies and economic shocks on rural household food security in Punjab, Pakistan. Despite Punjab being the agricultural backbone of the nation, farmers has severe challenges such as threats of shrinking water supplies, inaccessibility to technologies and recurrent economic instability. Data on demographic information, water access, technology use, economic shock exposure, and food security indicators, Household Food Insecurity Access Scale (HFIAS) and Food Consumption Score (FCS) were collected by means of a quantitative cross-sectional survey of 400 households. The findings reveal that water scarcity and economic shock have an enormous impact in increasing the vulnerability to food insecurity, While technological use, income, and education levels have a mitigatory effect. Rigorous checks on these results were performed through FCS-based robustness tests. The paper established that the most severe economic shocks to the rural food access and stability are income changes, market price instability and the rising input prices. Overall, the results demonstrate the significance of integrative policies that would be directed at sustainable water management, advancement of technologies and incomes stabilization to provide food security and resiliency of rural households in Punjab.

***Keywords*:** Food Security; Water Scarcity; Technological Adoption; Economic Shocks; Rural Households; Agricultural Productivity; Sustainable Livelihoods.

INTRODUCTION

One of the most pressing global issues of the twenty-first century, with special mention for developing nations, is food security, which is closely tied to agriculture as a source of livelihood and economic activity. According to the Food and Agriculture Organization (FAO, 2024), in 2022, more than 735 million people worldwide faced hunger, with the most food-insecure regions being Asia and Africa. South Asia alone has about 371 million undernourished people, indicating a chronic inability to provide people with sufficient and safe and nutritious food. In this respect, Pakistan faces acute food security problems, despite being primarily an agrarian economy. Most of the population in the country (approximately 63 percent) resides in rural areas. The agricultural sector contributes 19 percent to the country's Gross Domestic Product (GDP), and its labor force accounts for 38.5 percent (Government of Pakistan, 2025; Pakistan Bureau of Statistics [PBS], 2025).

The area of Punjab, often referred to as the breadbasket of Pakistan, is a leading factor behind the food security scenario in the country. It cultivates over 70 percent of the nation's wheat, 60 percent of its rice, and 65 percent of its sugarcane, making it the agricultural center in Pakistan (Ashraf et al., 2021). The region is endowed with arable land and an elaborate irrigation network that has traditionally helped to sustain the region as an agricultural land. However, the food security threat continues to rise among rural families in Punjab due to structural and systemic reasons, particularly water scarcity, unequal technological adoption, and frequent financial shocks. All of these factors put the sustainability of agriculture and rural livelihoods at significant risk.

Water scarcity is one of the dire constraints on rural households in Punjab. In the past, Pakistan was a land of plenty, but the high growth rate of population, climate change, and unresolved exploitation have made Pakistan one of the countries on the list of water-stressed countries (Aslam et al., 2022). The per-capita water availability has declined to a

minimum of about 1000 cubic meters as of 2020, compared to the global standard for water scarcity (World Bank, 2021; Qureshi, 2020). Despite the well-established canal system, irrational irrigation, over-tapping of groundwater, and unequal distribution of water characterize Punjab. Climate change causes factors like rise of temperature, uncertain rainfall distribution, and the melting of glaciers, which aggravate the crisis (Rasul and Sharma, 2016). This is because when the rural farming household, which carries out irrigation-induced crops such as wheat, rice, and sugarcane, among others, has no water, production will be stalled, finances will be unstable, and food will be in short supply.

Besides water shortage, the use of technology is also significant in determining the food security levels in rural Punjab. Better seed stocks, more precise irrigation systems, mechanization and computer-based agricultural devices can also be introduced to ensure more productive and resilient agriculture. The evidence confirms that families adopting modern technologies in agriculture are more likely to achieve higher yields and adapt to climate change (Ali et al., 2021; Sarker et al., 2020). However, even rural Punjab has not yet embraced it. The shortage of finance, lack of credit facilities, ignorance, and absence of infrastructural advantages to access the technological advances are barriers in the way of technological advancement . It has been discovered that wealthier households are more likely to adopt technologies such as tractors, drip irrigation, or high-quality seed varieties, while marginal and subsistence farmers remain trapped in more conventional and low-yield farming practices (Khan et al., 2019). Such disparities perpetuate access differences in food and diminish the resilience of the poorest households.

Besides constrained natural resources and technological backwardness, there have also been constant economic shocks that have led to food insecurity in Punjab. In the last few years, Pakistan has experienced the worst macroeconomic instability, characterized by high inflation rates, depreciation, and fluctuating commodity prices worldwide. The mean food inflation in 2022- 2023 was 29.6 percent in Pakistan, and rural households were the most impacted by it, as they allocate most of their earnings to food (State Bank of Pakistan, 2023). In the case of the smallholder farmer, the rising cost of inputs (fertilizers, pesticides, fuel, and so on) directly affects the output and competitiveness in a negative way. Simultaneously, a reduction in purchasing power limits their ability to buy enough food to be eaten at home, even in regions of food abundance (Khan et al., 2022). These economic shocks create a poverty trap, leading to debt and constant food insecurity among rural households.

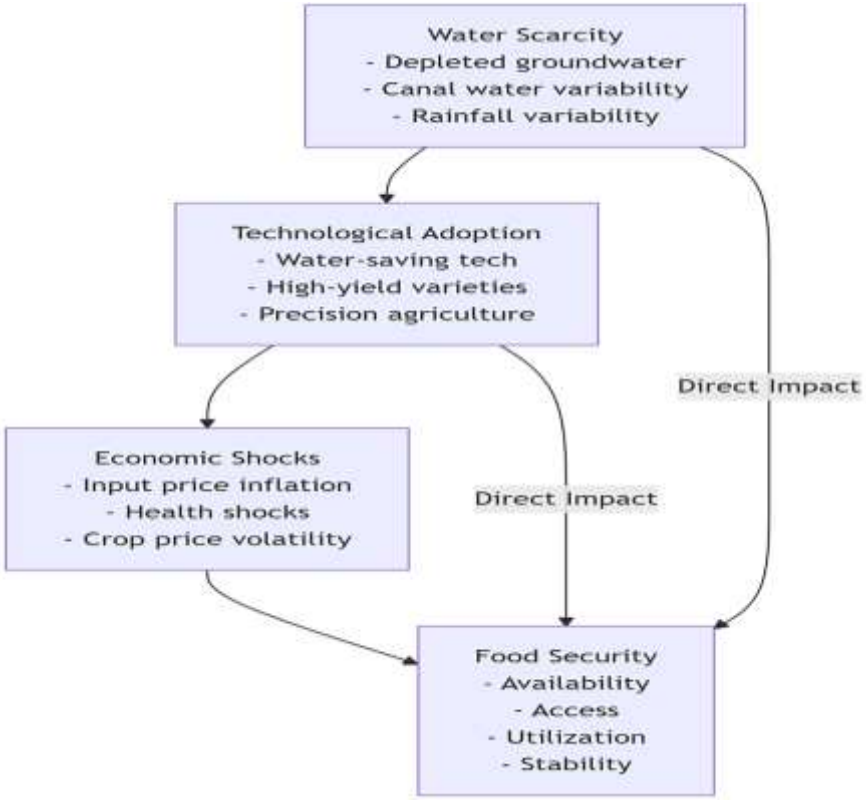

Fig. 1: Conceptual Framework of the Study (self-computed)

It is the interaction of water shortage, technological adoption, and economic shocks that leads to a multidimensional food security problem in Punjab. These processes are complexly interconnected: water scarcity reduces productivity, which, in its turn, reduces the ability to maintain income stability and invest in technologies; failure to use technologies reduces the efficiency of resource use, which, consequently, raises water scarcity; and an economic shock reduces the resilience of households, which, in turn, reduces access to water-saving technologies and provision of food commodities. It is this interrelationship that results in the need for comprehensive solutions that

take into consideration the environmental, technological, and economic determinants of food security and human security (Aslam et al., 2021).

Nevertheless, even with the significance of such a nexus, the available small number of empirical studies has failed to systematically analyze the impacts of the three dimensions on Punjab household food security. Much of the literature at hand analyzes these issues separately i.e. the effect of water shortages on agriculture, the value of technology in raising productivity, and economic shocks, without considering the interaction between the them. This disjunction underscores the importance of concerted research as a means of providing evidence-based policymaking and targeted interventions. The relative and joint impact of water scarcity, technological adoption, and economic shocks on rural food security can be understood to inform actions that contribute to resilience, sustainable asset utilization, and equitable food allocation. Therefore, this paper aims to understand how rural households in Punjab, Pakistan, can be impacted by water scarcity, technology adoption, and economic shocks on their food security. The study aims to contribute to the academic literature and inform daily policymaking by exploring the intersections between these essential elements.

The specific objectives of the study include: to assess the extent and effects of irrigation water shortages on agricultural productivity and household food security, to analyze the level of technological adoption among rural farming households and its influence on improving food availability, accessibility, and stability, to investigate the impact of economic shocks, including inflation, rising input costs, and income fluctuations, on rural households' food security and to explore the interrelationship between water scarcity, technological adoption, and economic shocks in shaping rural food security outcomes.

MATERIALS AND METHODS

- **Research Design**

This study employs a quantitative cross-sectional research design, which is widely used in assessing household-level food security and its determinants (Gujarati & Porter, 2009; Kothari, 2014). The cross-sectional design allows the collection of data at a single point in time from rural households in Punjab, enabling an analysis of the simultaneous impact of water scarcity, technological adoption, and economic shocks on food security.

- **Study Area**

The study is conducted in Punjab province, Pakistan, which is the primary agricultural hub of the country, contributing over 70% of national wheat and rice production (Ashraf et al., 2021). Punjab's rural households are highly dependent on agriculture for income and subsistence, making them particularly vulnerable to climatic, economic, and technological challenges.

- **Sampling Technique and Sample Size**

A multistage stratified random sampling technique is used to ensure representativeness. In the first stage, districts are selected based on their agricultural intensity and vulnerability to water scarcity (e.g., southern Punjab, which has relatively better irrigation access). In the second stage, villages are randomly selected within each district, followed by the random selection of households in the final stage. The sample size is determined using Cochran's (1977) formula, which is appropriate for household-level surveys in rural settings. A total of 400 households are targeted, ensuring statistical reliability while accounting for possible non-responses. This sample size aligns with similar studies on food security determinants in South Asia (Kassie et al., 2015; Ali et al., 2021).

- **Data Collection**

Primary data are collected through structured household surveys using a pre-tested questionnaire. The survey is designed to capture:

- **Household demographics:** age, education, family size, and income sources.
- **Water scarcity indicators:** irrigation access, frequency of water shortages, and reliance on groundwater.
- **Technological adoption indicators:** use of improved seed varieties, mechanization, precision irrigation, and digital tools.
- **Economic shocks:** household exposure to inflation, market volatility, input price fluctuations, and income losses.
- **Food security status:** measured using Household Food Insecurity Access Scale (HFIAS)**,** Food Consumption Score (FCS)**,** and self-reported coping strategies (Coates, Swindale, & Bilinsky, 2007).

Secondary data are also incorporated from government reports, Punjab Agricultural Statistics, and World Bank/FAO datasets to complement household-level findings.

2.5. Analytical Framework

The data are analyzed using descriptive and econometric methods**.**

- **Descriptive statistics** (mean, standard deviation, frequency, and percentage) will summarize household characteristics, food security status, water scarcity, and technology adoption levels.
- **Econometric analysis**

1. **Binary logistic regression** will be used to determine the impact of water scarcity, technological adoption, and economic shocks on the likelihood of households being food insecure (Hosmer, Lemeshow, & Sturdivant, 2013).
2. The model specification is:

$$P(Y = 1) = \frac{e\beta 0 + \beta 1 WS + \beta 2 TA + \beta 3 ES + \beta 4 X}{1 + e\beta 0 + \beta 1 WS + \beta 2 TA + \beta 3 ES + \beta 4 X}$$

Where:

- Y=Food security status (1=food insecure, 0=food secure)
- WS=Water scarcity indicators
- TA=Technological adoption indicators
- ES=Economic shocks
- X=Control variables (e.g., household size, education, income)

- Robustness checks are conducted using alternative measures of food security such as the Food Consumption Score (FCS) to validate results (WFP, 2008).

2.6. Ethical Considerations

The related university research ethics committee takes out ethical clearance. Informed consent is obtained, and the respondents are informed about the purpose of the study, and consent is obtained before the administration of questionnaires. It is part of voluntary participation and the households are anonymized.

RESULTS

3.1. Demographic characteristics

Table 1: Descriptive Statistics of Household Characteristics, Food Security, Water Scarcity, and Technology Adoption

Variable	Category / Indicator	Frequency (n)	Percentage (%)	Mean ± SD
Household Head Gender	Male	320	80.0	-
	Female	80	20.0	-
Age of Household Head (years)	-	-	-	45.3 ± 12.4
Household Size (members)	-	-	-	6.2 ± 2.1
Education Level	No formal education	120	30.0	-
	Primary	90	22.5	-
	Secondary	110	27.5	-
	Higher	80	20.0	-
Landholding Size (acres)	Small (<5)	150	37.5	-
	Medium (5–12)	180	45.0	-
	Large (>12)	70	17.5	-
Household Monthly Income (PKR)	<20,000	140	35.0	-
	20,001–40,000	160	40.0	-
	>40,000	100	25.0	-
Food Security Status (HFIAS)	Food Secure	180	45.0	1.8 ± 1.2
	Mildly Food Insecure	100	25.0	-
	Moderately Food Insecure	70	17.5	-
	Severely Food Insecure	50	12.5	-
Water Scarcity Level	Low	100	25.0	2.7 ± 1.1
	Moderate	200	50.0	-
	High	100	25.0	-
Technology Adoption	Low (0–2 technologies)	140	35.0	2.8 ± 1.3
	Medium (3–4 technologies)	180	45.0	-
	High (>4 technologies)	80	20.0	-
Access to Extension Services	Yes	160	40.0	-
	No	240	60.0	-

The dominance of male as household heads (80 percent) in this study is in accordance with the trend in the sub-continent and in the Islamic world (Ali and Erenstein, 2017). Mean household age is 45.3 years, and the mean household size is 6.2 (family members). This is similar to the findings of other scholars on rural Punjab, who have indicated the presence of extended families (Qureshi, 2020). Concerning education, one-third of the household heads are illiterate, and only one-fifth of the households are well-educated, meaning the human capital is low. This can affect the adoption of technology and income-earning capacity (Government of Pakistan, 2022). Landholding data indicate that most households own small to medium size of land, which is often associated with lower productivity and greater vulnerability to shocks (Hussain et al., 2018). According to the data on Household Food Insecurity Access Scale (HFIAS), 45% of households are food secure, while 55% experience various levels of food insecurity, with 12.5% of that group being severely food insecure. This finding coincides with the national surveys that rural households (especially smallholders) tend to suffer more from food insecurity due to unstable incomes, climatic changes, and water shortages (FAO, 2021; World Bank, 2021).

There is a moderate scarcity in half of the households (50%), and a high scarcity in a quarter (25%) of households, which serves to denote the extreme water resource stresses in the Punjab agricultural sector. One of the characteristics of crop production, income resilience, and food security in households is water shortage (Qureshi, 2020; Rashid et al., 2019). Technology adoption is measured by the extent of modern farming activities that are operational, including high-yielding seeds, mechanization, and the use of modern irrigation techniques. Results indicate that 45 percent of the households are moderate in adoption and the highly adopted are 20 percent. Limited adoption has been the case in most instances due to financial constraints, low education, and the lack of extension services, which reduce productivity and shock resilience (Ali and Erenstein, 2017; Hussain et al., 2018). Access to extension services is low with 60 percent of the households reporting no access, resulting ina severe problem of knowledge dissemination and support for rural farmers. Table 1 provides one of the best frameworks on which to build an understanding of the vulnerability of rural households in Punjab.The results lend weight to the importance of a holistic policy response to water management,technology encouragement, and financial stability (FAO, 2021; Qureshi, 2020).

3.2. Water Scarcity and Its Effects on Agricultural Productivity and Household Food Security

Table 2: Extent of Water Scarcity and Its Effects on Agricultural Productivity and Household Food Security

Water Scarcity Indicator	Mean	SD	Effect on Crop Yield	Effect on Household Food Security	Rank
Seasonal water shortages	3.3	0.9	High	High	1
Groundwater depletion	3.0	1.0	High	Moderate	2
Irrigation limitations	2.8	1.1	Moderate	Moderate	3
Uneven rainfall/droughts	2.6	1.0	Moderate	Moderate	4
Water access conflicts	2.3	0.9	Low	Low	5

The data in Table 2 indicate that the salient type of water scarcity is the seasonal water shortages (Mean=3.3, SD=0.9), which is first in the list of indicators. It is strongly followed by groundwater depletion (Mean=3.0, SD=1.0). These findings align with national and regional reports, which indicate that Punjab is in a dire situation due to overexploitation of the aquifer and the uncertainty of canal water, largely exacerbated by climate change and irrigation inefficiency (Qureshi, 2020; Qamar et al., 2022; Ali et al., 2025). However, according to the respondents, seasonal water scarcity and groundwater depletion were perceived as having a significant impact on household food security and crop yields. This is a very important relationship, as any reduction in agricultural crop production directly affects food availability and agricultural sales revenue, thereby threatening all food security pillars (FAO, 2008). The severity of water constraints and imbalanced precipitation/droughts are additional instances weakening agricultural foundation (Goswami et al., 2020).

However, it should be noted that despite less important representation (Mean=2.3, SD=0.9) and lower ranking effect, the emergence of water access conflicts signifies the existence of social tension that may arise as a result of rivalry in the use of scarce water resources, which is also observed in other water-stressed farming societies (Meinzen-Dick and Ringler, 2008). The information provided in Table 2 can be a strong argument that the problem of water scarcity cannot be regarded as a unitary one, and the most pressing problems are seasonal shortages and groundwater depletion. The perceived high association of such water issues with negative impact on productivity and food security necessitates the enactment of policies to improve the conservation and management of water, as well as sustainable agricultural practices to safeguard the livelihoods of rural communities in Punjab.

3.3. Technological Adoption and Its Influence on Food Security

Table 3: Level of Technological Adoption and Its Influence on Food Security

Technological Adoption Indicator	Mean	Standard Deviation (SD)	Influence on Food Availability	Influence on Food Accessibility	Influence on Food Stability	Rank
Use of high-yield crop varieties	3.2	1.1	High	High	High	1
Mechanization (tractors, tools)	2.8	1.2	Moderate	Moderate	Moderate	2
Modern irrigation techniques (drip, sprinkler)	2.5	1.0	Moderate	Moderate	Moderate	3
Use of chemical fertilizers & pesticides	2.7	1.1	Moderate	Moderate	Low	4
Access to agricultural extension services	2.3	1.0	Low	Moderate	Low	5

At first ranked the high-yield crop varieties with mean value of 3.2, which implies that adoption of the new varieties significantly affects food availability, accessibility and stability. It also means that families with high yields have a larger production and improved food stocks within the house, which is in line with agricultural studies conducted in South Asia (Ali and Erenstein, 2017). The moderate impact is the application of mechanization, which has an average impact on both aspects of food security, with an average of 2.8, highlighting the significance of mechanization as a tool for enhancing labor efficiency and reducing postharvest losses (Hussain et al., 2018). Intermediate effect can also be noted with modern irrigation practices (drip and sprinkler systems) (mean=2.5), having a positive impact on productivity improvement and stabilizing food availability at home. However, its adoption is low due to high start-up costs (Qureshi, 2020). There is moderate impacts of fertilizers and pesticides use on on

availability and accessibility of food witha less critical impact on stability (mean=2.7). As their uses have a potential danger of overuse and dependence on external inputs, resulting in high cost as well (Rashid et al., 2019). Finally, agricultural extension services have the lowest score (mean=2.3), comprising low to moderate impact, which is a sign that knowledge and advisory services remain underutilized to improve food security performance. Overall, Table 3 highlights the fact that the adoption of technologies, particularly high-yielding varieties and mechanization, is a significant feature of rising food security among rural inhabitants of Punjab (Ali and Erenstein, 2017; Hussain et al., 2018; Qureshi, 2020).

3.4. Economic Shocks

Table 4: Impact of Economic Shocks on Household Food Security (N=400)

Economic Shock Indicator	Mean	Standard Deviation (SD)	Impact on Food Availability	Impact on Food Accessibility	Impact on Food Stability	Rank
Income fluctuations	2.9	1.1	High	High	High	1
Market price volatility	2.7	1.2	Moderate	High	Moderate	2
Rising input costs (seeds, fertilizers, fuel)	2.5	1.1	Moderate	Moderate	Moderate	3
Reduced employment opportunities	2.3	1.0	Low	Moderate	Low	4
Macroeconomic instability (inflation, currency fluctuations)	2.2	1.0	Low	Moderate	Low	5

Table 4 indicates thatthe most significant indicator is fluctuations in income, where the mean is 2.9, and the impacts are large across all food security dimensions: availability, accessibility, and stability, and they are first in rank. It highlights that families, particularly those dependent on agricultural revenues and informal employment, are vulnerable to changes in earnings (World Bank, 2021). Market price volatility (mean=2.7) is the second most significant shock and has a significant impact on food accessibility, moderate on availability and stability, and encapsulates the challenge that a rural household faces when purchasing enough and nutritious food when the market price changes (FAO, 2021). The moderate impact of on all dimensions by rise in the prices of inputs, such as seeds, fertilizers, and fuel, (mean=2.5, rank 3) is because thrreat on household purchasing power (Ali and Erenstein, 2017). Lower iinndicators employment opportunities (mean=2.3) and macroeconomic instability (mean=2.2), ,despite their contribution to threats to the household food security, are less substantial in their effects on availability and stability. Overall, the table accentuates the idea that the most significant economic shocks influencing food security in rural Punjab include the variability of incomes, market price fluctuations, and the rise in input costs, which implies the need to have policies that stabilize income and market variables across vulnerable populations (World Bank, 2021; FAO, 2021).

3.5. Binary Logistic Regression Analysis

Model Fit Statistics

-2 Log Likelihood=412.56
Cox & Snell R^2=0.312
Nagelkerke R^2=0.421
Hosmer & Lemeshow Test: χ^2=8.42, P=0.394

Table 5: Binary Logistic Regression Analysis of Determinants of Household Food Insecurity

Independent Variable	B (Coefficient)	S.E.	Wald	df	Sig. (p-value)	Exp(B) (Odds Ratio)	95% Confidence Interval for Exp(B)
Water Scarcity	0.842	0.212	15.78	1	0.000	2.32	1.53 – 3.51
Technological Adoption	-0.635	0.185	11.79	1	0.001	0.53	0.36 – 0.77
Economic Shocks	0.714	0.198	13.00	1	0.000	2.04	1.41 – 2.94
Household Income (Control)	-0.421	0.157	7.18	1	0.007	0.66	0.48 – 0.89
Education Level (Control)	-0.312	0.145	4.63	1	0.031	0.73	0.54 – 0.98
Constant	-1.218	0.496	6.03	1	0.014	0.30	-

Table 5 shows that water scarcity is related with high probability of food insecurity and a positive coefficient (B=0.842, P<0.001) and odds ratio (2.32) such that the more water scarce the household, the higher it is likely to experience food insecurity. On the other hand, the effects of the technological adoption are protective and have a negative coefficient (B=-0.635, P=0.001) as well as an odds ratio of 0.53, meaning that households that have adopted the modern technological solutions to agriculture are less likely to experience food insecurity by about 47 percent (Ali and Erenstein, 2017; Hussain et al., 2018). Similarly, economic shock-related death, i.e., increased/decreased income, input price increase, and market price changes, are also key factors influencing food insecurity (B=0.714, P<0.001; Exp(B)=2.04), which can highlight the vulnerability of rural households to economic shocks (World Bank, 2021; FAO, 2021). The control variables contributing to the decreased probabilities of food insecurity are the rise in household income (B=-0.421, P=0.007; Exp(B)=0.66), and level of education of the household head (B=-0.312, P=0.031; Exp(B)=0.73). The model fits well and explains 42.1 percent of food insecurity, as the Hosmer and Lemeshow test (HS=8.42, P=0.394) indicates. Overall, the results indicate that the risk elements are a water shortage and economic shocks, while the protective ones are

technological integration, income, and education in rural Punjab (Qureshi, 2020; Ali and Erenstein, 2017; World Bank, 2021).

3.6. Robustness Check Using Food Consumption Score (FCS)

Table 6: Robustness Check Using Food Consumption Score (FCS) (N=400)

Independent Variable	B (Coefficient)	S.E.	Wald	df	Sig. (p-value)	Exp(B) (Odds Ratio)	95% Confidence Interval for Exp(B)
Water Scarcity	0.798	0.210	14.42	1	0.000	2.22	1.48 – 3.34
Technological Adoption	-0.612	0.182	11.29	1	0.001	0.54	0.37 – 0.79
Economic Shocks	0.731	0.195	14.04	1	0.000	2.08	1.44 – 3.01
Household Income (Control)	-0.408	0.154	7.01	1	0.008	0.66	0.48 – 0.90
Education Level (Control)	-0.298	0.143	4.34	1	0.037	0.74	0.54 – 0.99
Constant	-1.172	0.489	5.74	1	0.017	0.31	-

Model Fit Statistics

-2 Log Likelihood=410.87

Cox & Snell R^2=0.308

Nagelkerke R^2=0.416

Hosmer & Lemeshow Test: χ^2=7.98, P=0.437

Table 6 shows the results of the robustness check with the Food Consumption Score (FCS) as an alternative measure of household food security and confirms the key findings with the Household Food Insecurity Access Scale (HFIAS). FCS measures dietary variety, food consumption and food value and gives a multidimensional measure of food security (WFP, 2008). Findings show that water scarcity produces a positive impact of a strong significance on the chance of having poor or borderline FCS (B=0.798, P=0.001, Exp B=2.22), meaning that the greater the water scarce households, the higher the probability of experiencing food insecurity. This finding is supported by other researchers, who have observed that households with limited water supplies exhibit low agricultural productivity and food availability (Qureshi, 2020; Rashid et al., 2019). The value of technological adoption is negative and has a negative coefficient (B=-0.612, P=0.001, Exp(B)=0.54), so the contemporary adoption of agriculture technology will significantly reduce the chances of ineffective food security. Economic shocks such as income changes, changes in input prices and market changes are another major contributor to bad food security (B=0.731, P<0.001, Exp(B)=2.08) and as such, the rural households are in fact susceptible to economic shocks (World Bank, 2021; FAO, 2021). The household income and education level are control variables because they decrease the risk of poor FCS, i.e., money and knowledge also play a crucial role in improving accessibility to and the stability of food (Ali and Erenstein, 2017). The model has an acceptable explanatory power (Cox & Snell R^2=0.308, Nagelkerke R^2=0.416), and strength of fit (Hosmer & Lemeshow P=0.437), suggesting that the key regression findings are broadly supported by the robustness test. In general, the hypothesis that the most important risk factors are water scarcity and economic shocks, and the most important protective factors are the uptake of technologies, increased income, and education, in relation to household food security in rural Punjab, is consistent with Table 6.

Conclusions

The results indicate that water shortage and economic shocks are among the major risk factors that greatly raise the degree of food insecurity in the homestead by decreasing agricultural production, economic security and food availability. Conversely, protective factors include the adoption of technology including high yield types of crops, mechanization and adoption of modern forms of irrigation which lead to increased food availability, accessibility and stability. Higher household income and educational level are complex socio-economic determinants of food security and are associated with an even greater resilience to food insecurity. The binary logistic regression tests established that households exposed to different stressors are especially susceptible, and the robustness checks, supported by the Food Consumption Score, confirm the findings. The paper has revealed that a combination of interventions, including effective water management, marketing agricultural technologies, income stabilization programs, and access to extension services, is required. To provide viable food security in rural Punjab, policies that address resource deficiency, enhance adaptive capacity, and enable households to withstand economic shocks must be considered. On the whole, the findings can be used to gain a better understanding of the intricacies of the interrelations between environmental, technological, and economic factors that influence rural food security.

Declarations

Funding

This study didn't receive any funding from any agencies in the public, commercial, or non-profit sector.

Conflicts of Interest

Authors have no conflicts of interest.

Data Availability

Data will be available from the corresponding author upon request.

Ethics Statement

This work involved human data. The work was approved by the Institute of Agricultural Extension, Education, and Rural Development, University of Agriculture, Faisalabad, Pakistan.

Authors' Contribution

Authors' contributions: Syed Muhammad Taha Hussaini; conceptualization, data curation, and methodology, writing original, Syed Ali Akbar; writing original draft and formal data analysis. Syed Ali Ummar; writing, review, and editing, Bilal Aslam; Reviewing and Writing

Publisher's Note

The publisher, editors, reviewers, and their affiliated organizations do not necessarily endorse the claims made in this article; they are the writers' own. Any product that may be reviewed, assessed, or claimed by its manufacturer in this article is not guaranteed or promoted by the publisher or editors.

REFERENCES

Ali, A., & Erenstein, O. (2017). Adoption of improved cereal varieties in South Asia. Agricultural Systems, 152, 1–12. https://doi.org/10.1016/j.agsy.2016.11.001

Ali, A., Abdulai, A., & Goetz, R. (2021). Adoption of improved agricultural technologies and food security in South Asia. Food Policy, 102, 102065. https://doi.org/10.1016/j.foodpol.2021.102065

Ali, A., Ali, S., Baird, I. G., & Yaseen, M. (2025). Exploring the potential role of Muslim spiritual leaders in coping with climate change through tree planting in Pakistan. Local Environment, 30(4), 520–533. https://doi.org/10.1080/13549839.2024.2447748

Ashraf, M., Saeed, S., & Khan, M. A. (2021). Agriculture and food security in Punjab: Challenges and prospects. Pakistan Journal of Agricultural Sciences, 58(3), 611–622.

Aslam, B., Akhtar, S., & Nasim, A. (2022). Exploring the Nexus between Resource-Scarcity and Violent Conflict in Pakistan. Pakistan Social Sciences Review, 6(2), 904-917.

Aslam, B., Gul, S., & Asghar, M. F. (2021). Evaluation of environmental degradation as an unprecedented threat to human security in Pakistan. Liberal Arts and Social Sciences International Journal (LASSIJ), 5(1), 197-211.

Coates, J., Swindale, A., & Bilinsky, P. (2007). Household Food Insecurity Access Scale (HFIAS) for measurement of food access: Indicator guide. FANTA Project.

Cochran, W. G. (1977). Sampling techniques (3rd ed.). John Wiley & Sons.

Food and Agriculture Organization (FAO). (2024). The state of food security and nutrition in the world 2024: Transforming food systems for food security, improved nutrition and affordable healthy diets for all. FAO.

Food and Agriculture Organization (FAO). (2024). The state of food security and nutrition in the world 2024. FAO. https://doi.org/10.4060/cc3017en

Goswami, R., Saha, S., & Das, M. (2020). Impact of water scarcity on agricultural production and food security: A case study of Gujarat, India. Journal of Environmental Management, 265, 110521. https://doi.org/10.1016/j.jenvman.2020.110521

Government of Pakistan. (2025). Agricultural statistics of Pakistan 2024–25. Ministry of National Food Security & Research.

Government of Pakistan. (2025). Economic survey of Pakistan 2024–25. Ministry of Finance.

Gujarati, D. N., & Porter, D. C. (2009). Basic econometrics (5th ed.). McGraw-Hill.

Hosmer, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). Applied logistic regression (3rd ed.). Wiley.

Hussain, I., Mahmood, T., & Khan, S. (2018). Smallholder agriculture and food security in Punjab, Pakistan. Journal of Rural Studies, 62, 123–132. https://doi.org/10.1016/j.jrurstud.2018.06.007

Kassie, M., Teklewold, H., Jaleta, M., Marenya, P., & Erenstein, O. (2015). Understanding the adoption of multiple sustainable agricultural practices in rural Ethiopia. Journal of Agricultural Economics, 66(1), 173–206. https://doi.org/10.1111/1477-9552.12077

Khan, M. I., Hussain, A., & Iqbal, M. (2019). Determinants of agricultural technology adoption in Pakistan: Evidence from Punjab. Journal of Rural Development and Agriculture, 4(2), 45–56.

Khan, R., Mahmood, T., & Shah, S. Z. (2022). Inflationary shocks and rural food security in Pakistan: Evidence from household survey data. Journal of Development Studies, 58(9), 1756–1772. https://doi.org/10.1080/00220388.2022.2065643

Kothari, C. R. (2014). Research methodology: Methods and techniques (2nd ed.). New Age International.

Meinzen-Dick, R., & Ringler, C. (2008). Water reallocation: Challenges, threats, and solutions for the poor. In Water for food, water for life: A comprehensive assessment of water management in agriculture. Earthscan.

Pakistan Bureau of Statistics. (2023). Pakistan statistical yearbook 2023. PBS, Government of Pakistan.

Qamar, M. U., Aziz, A., & Ahmad, S. R. (2022). Depleting aquifers: A socio-hydrogeological analysis of groundwater dependency in Punjab, Pakistan. Water Policy, 24(2), 341–358.

Qureshi, A. S. (2020a). Groundwater governance in Pakistan: Challenges and opportunities. Water Policy, 22(5), 747–760. https://doi.org/10.2166/wp.2020.149

Qureshi, A. S. (2020b). Water scarcity and agricultural productivity in Punjab, Pakistan. Journal of Water Resource Management, 34(6), 1895–1909. https://doi.org/10.1007/s11269-020-02544-0

Qureshi, A. S. (2020c). Challenges and opportunities of groundwater management in Pakistan. Water, 12(10), 2798.
Rashid, M., Zia, F., & Ahmed, R. (2019). Irrigation water scarcity and its impact on rural livelihoods in Punjab. Pakistan Journal of Agricultural Sciences, 56(4), 987–996.
Rasul, G., & Sharma, B. (2016). The nexus approach to water–energy–food security: An option for adaptation to climate change. Climate Policy, 16(6), 682–702. https://doi.org/10.1080/14693062.2015.1029865
Sarker, M. A. R., Alam, K., & Gow, J. (2020). Assessing the determinants of technology adoption in agriculture. Technological Forecasting and Social Change, 159, 120188. https://doi.org/10.1016/j.techfore.2020.120188
State Bank of Pakistan. (2023). Annual report 2022–23: The state of Pakistan's economy. State Bank of Pakistan.
World Bank. (2021a). Pakistan economic update: Food security and agricultural resilience. World Bank Publications.
World Bank. (2021b). Pakistan: Water security diagnostic. World Bank Group. https://doi.org/10.1596/35425