



Role Of FWRDP Water Management Initiatives in Enhancing Wheat Productivity in District Bajaur

Dr. Ikramullah

Planning Officer, ADC(F&P) Office Civil Colony Khar, District Bajaur

Ikrambjr@gmail.com

Dr. Bilal Khan Afridi

Research Analyst, Planning & Development Department, Govt. Of Khyber Pakhtunkhwa

bilalafridil@gmail.com

Dr. Farahnaz Turi

Assistant professor of economics, Higher education archives and libraries Department, Khyber Pakhtunkhwa

Farahnaz.turi@gmail.com

Dr. Shahid Iqbal *

Centre for Disaster Preparedness & Management/IER/Assistant Directorate of Advanced Studies, University of Peshawar

shahidiqbalkhan@uop.edu.pk

* Corresponding Author

ABSTRACT

FATA Water Resources Development Project (FWRDP) operates in many regions of the erstwhile FATA, including Bajaur, and one of its primary components is on-farm water management (OFWM). This study investigates how agricultural production of wheat in district Bajaur is transformed by on-farm water management practices. This study is based on household data from 120 farmers that were gathered using a pre-tested questionnaire. A binary logit model was used to identify determinants of OFWM on agricultural productivity of wheat. The study found that the age of respondents, farming experience, working members, water availability and community organization membership were statistically significant and positively

related to OFWM effects on agricultural productivity of wheat. On the other side, variables such as education level, access to agriculture extension, credit and land tenancy were statistically non-significant and had an inverse effect on the agricultural productivity of wheat. The overall model was significant as shown by $p < 0.05$ which depicts that the socio-economic characteristics of the population are the main factors contributing to the effects on OFWM on agricultural productivity of wheat crop. It is important to consider these factors when designing policies and programs aimed at improving water management practices in agriculture to promote sustainable economic development and increase crop yields.

Keywords: On-farm water management, FWRDP, wheat, agricultural productivity

INTRODUCTION

The Asian Development Bank (ADB)-funded FATA Water Resources Development Project (FWRDP) is an integrated rural development project that has been operating since 2015 in various districts recently merged to Khyber Pakhtunkhwa. The project's main components are community organization, irrigation infrastructure development, enhanced water-shed management, on-farm water management, incentives and trainings, etc (FWRDP, 2012). This study area encompasses District Bajaur, one of three erstwhile FATA Districts, namely Khyber, Mohmand, and Bajaur. An estimated 2.65 million people live in the three districts (Government of Pakistan, 2017).

Food security and efficient irrigation water management are the two main concerns facing the globe today. Low water output, expensive water management systems, and ineffective irrigation practices exacerbate these problems. An integrated strategy for sustainable water management is a critical component of the solution. The main element that improves water productivity is farm-level irrigation scheduling (Ali et al., 2022). Irrigated agriculture plays a vital role in securing food for 220 million people in Pakistan. Challenges in farming prompted a proposed governance model, stressing increased investment in irrigation infrastructure, on-farm water management, and resource conservation technologies for improved agricultural productivity (Ul Hasan et al., 2021). Improving on-farm water management practices for increased agricultural production is a key component of an integrated approach that should be prioritized equally alongside other income-generating initiatives in order to effectively eradicate poverty and lay the groundwork for sustainable development in rural areas (Luqman et al., 2013).

According to the Pakistan economic survey (2022-23), major crops added 18.23% to the value added of the agriculture sector and 4.18% to the GDP in 2022–2023. One of the main crops, wheat, was grown on 9,043 thousand hectares, an increase of 0.7% over the previous year. With an output of 27.634 million tons, a 5.4% increase over the previous year, wheat contributes 1.9% of GDP and 8.2% of agriculture value addition.

Producing wheat helps combat malnutrition and makes farms more sustainable. In order to achieve stability and overcome production barriers, cooperation between government institutions and international organizations is essential. State intervention is necessary, particularly in providing essential production inputs and water for irrigation (Ahmed et al., 2011).

For Pakistan's food security, increasing the yield of wheat and other crops is essential. Promoting certified seeds, offering credit for inputs, subsidized fertilizers, crop variety optimization, and sufficient water supply for agriculture are some strategies that can help to achieve food security. (Ahmad, 2009). In Pakistan, inadequate management of farmland has impeded economic growth (Khan, 2015). Access to irrigation water is important to enhance crop productivity, increase incomes, and reduce poverty, emphasizing the need for targeted development in poor communities.(Hussain and Hanjra, 2003).

FWRDP focuses on enhancing on-farm water management by training community organizations in the study area on proper irrigation water use. Engaging water user associations in Pakistan improves on-farm water use efficiency, positively impacting agricultural productivity. Active community involvement is crucial for sustainable on-farm water use and subsequent agriculture production (Chaudhry, 2017). In Pakistan, common farmers face issues with traditional irrigation and low crop productivity. Introducing on-farm water management technologies like precision land leveling and drip irrigation aims to save water and boost crop yield (Bakhsh et al.,2016)

According to published research, implementing a number of strategies for sustainable water management in agriculture includes improving irrigation methods, plant and soil practices, water pricing, reusing wastewater, and involving farmers (Chartzoulakis and Bertaki, 2015). More evidence of the many benefits of improved water management in many contexts is provided by the literature. According to Boretti and Rosa (2019), there will be a 60% rise in the world's food consumption by 2050, requiring higher yields and more acreage. Schultz et al. (2005) emphasized the fundamental role of water management in addressing challenges linked to population growth, food production, and sustainable rural development. Agriculture sector's rapidly shrinking contribution to the labor force and gross domestic product of the country, a new governance paradigm is needed. In order for farming to succeed, efficient on-farm water management techniques must be prioritized (Ul Hasan et al., 2021). According to Ali et al (2022), Pakistan faces an imminent water crisis threatening food security. Despite a vast irrigation system, over 90% of freshwater is used for agriculture, contributing to a water-intensive economy. Agriculture, constituting 24% of GDP, exacerbates the crisis due to seepage, poor management, and pollution. Climatic factors worsen the situation. Addressing this requires awareness campaigns, water budgeting, technology adoption, equitable water distribution, and government regulations.

Numerous advantages of better water management in a variety of scenarios are demonstrated by literature. For instance, rural households in Pakistan, primarily

adopt four water-management practices (bund making, deep plowing, stress-tolerant varieties, and irrigation supplements). The wealth, education, and gender (male) positively influence the adoption of these practices. Propensity score matching demonstrates that adopting improved water-management practices enhances wheat and rice yields, household income, food security, and reduces poverty (Ali et al., 2018). The objective of this research paper is to analyze the effects of on-farm water management by FWRDP on agricultural productivity of wheat crop in Bajaur District in Khyber Pakhtunkhwa province of Pakistan.

Material And Methods

Sample design and sample size

This study adopted a multi-stage sampling procedure. FWRDP was working in the entire Bajaur district which had eight Tehsils. For the purpose of this study, two tehsils namely Khar and Utman Khel were selected randomly (Fig. 1). The pilot study confirmed that FWRDP had constituted 81 community organizations (COs) in Bajaur district. Out of 81 COs, 57 COs were selected from two tehsils as a sample (42 in Khar and 15 in Utman Khel).

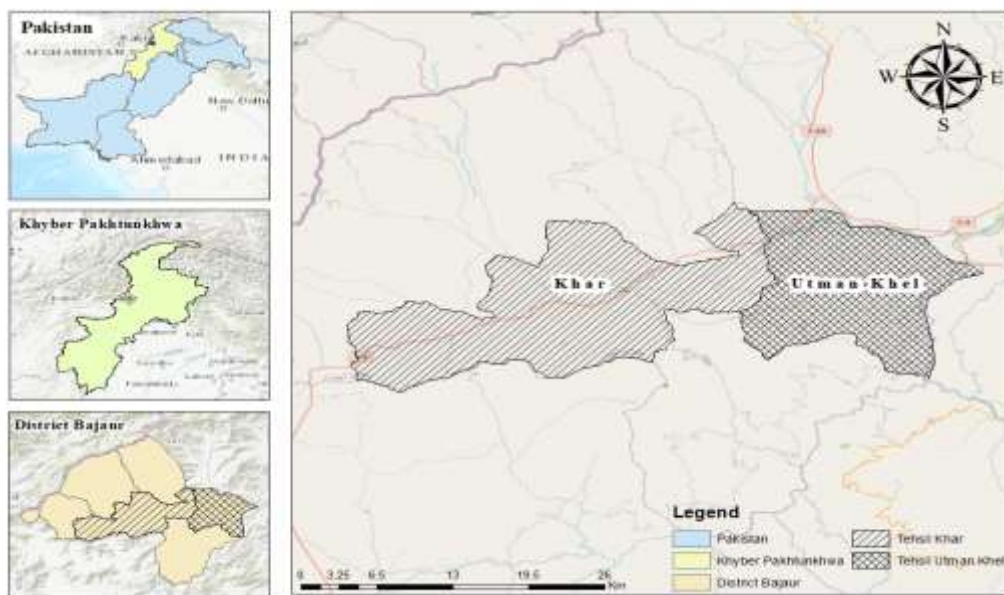


Figure 1: Map of the research area

In the second stage of sampling, 20 COs were selected using proportionate random sampling technique. The formula of proportionate sampling technique is as follows:

$$n_i = \frac{N_i}{N} * n \dots\dots\dots (1)$$

Where

- n_i = required number of sampled COs in each tehsil
- N_i = Total number of COs in each tehsil
- i = Number of tehsils in the study area ($i=1, 2$)
- N = Total number of COs in the study area
- n = Total sample size (COs)

Putting values in equation 1, the following sample size was determined for each tehsil.

$$\begin{aligned} n_1 &= 15/57 \times 20 &= 5 \text{ (Utman Khel)} \\ n_2 &= 42/57 \times 20 &= 15 \text{ (Khar)} \end{aligned}$$

As all households in the command area of a CO (a village) were beneficiaries of the project in terms of irrigation infrastructure development, therefore, in the third stage, a total of six beneficiaries were selected from each CO. Thus, the total number of households selected for the study was 120 households.

Data sources and data collection

For this study, primary data was collected from the beneficiary households through a questionnaire. A semi-structured questionnaire was specifically designed for this study which was pre-tested in the field before the final survey. The questionnaire was used to collect data from 120 households related to main objective of the study, which covered agricultural output per unit area measured as mounds/kannal, number of family labors involved in farming, farming experience, availability of water for irrigation, land tenancy, membership of the community organization, access to agricultural credit and agricultural extension services, etc.

Data analysis

The aim of this study was analyzing the effects of on-farm water management by FWRDP on agricultural productivity of wheat in Bajaur. In this study, the dependent variable was in binary form which measured if agricultural productivity of major crop (wheat) had been increased in response to on-farm water management of FWRDP or otherwise. Therefore, the following binary logic models were estimated.

$$\log\left(\frac{P}{1-P}\right) = \alpha_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 D_1 + \beta_5 D_2 + \beta_6 D_3 + \beta_7 D_4 + \beta_7 D_5 + \beta_7 D_6 \dots\dots(3.3)$$

Where:

- P = Probability of Y=1, 1-P = Probability of Y =0
- Y_i = increase in agricultural productivity of wheat (1 if Yes, 0 otherwise)
- X₁ = Age of the farmer (years)
- X₂ = Farming experience (years)
- X₃ = Family members involved in farming (in numbers)
- D₁ = Education level of the farmer (Categorical)
- D₂ = Availability of sufficient water throughout the cropping season (1 if yes, 0 otherwise)
- D₃ = Membership of the CO (1 if yes, 0 otherwise)
- D₄ = Access to agricultural credit (1 if yes, 0 otherwise)
- D₅ = Access to agricultural extension services (1 if yes, 0 otherwise)
- D₆ = land tenancy (1 if owner, 2 if tenant, 3 if both owner cum tenant)
- α = Intercept
- β_s = Coefficients of explanatory variables
- ε_i = Error term

RESULTS AND DISCUSSION

Description of the Explanatory Variables

Key factors influencing the impact of on-farm water management on the productivity of wheat are examined through a vector of potential determinants. Descriptive statistics for these determinants (explanatory variables) are presented in Table 1.

Table 1: Descriptive statistics of the variables used to predict wheat crop productivity

Variable description	Minimum	Maximum	Mean/ Proportion	Std. Deviation
<i>Quantitative Variables</i>				
Respondent age	22	70	40.67	10.982
Farming experience in years	1	40	18.12	8.722
Number of family labors involved in farming	1	13	4	2.353
<i>Qualitative Variables</i>			Proportion	
Qualification (Illiterate)			35	
Qualification (Primary/Middle)			36	
Qualification (Metric)			15	
Qualification (Intermediate)			6	
Qualification (Graduate) or above			8	
Water availability (Yes)			43	
Water availability (No)			57	
CO membership formed by FWRDP (Yes)			67	
CO membership formed by FWRDP (No)			33	
Access to credit (Yes)			7	
Access to credit (No)			93	
Access to Agri Ext: services (Yes)			61	
Access to Agri Ext: services (No)			39	
Land Tenancy (Owner)			40	
Land Tenancy (Owner cum Tenant)			52	
Land Tenancy (Tenant)			8	
No= 120				

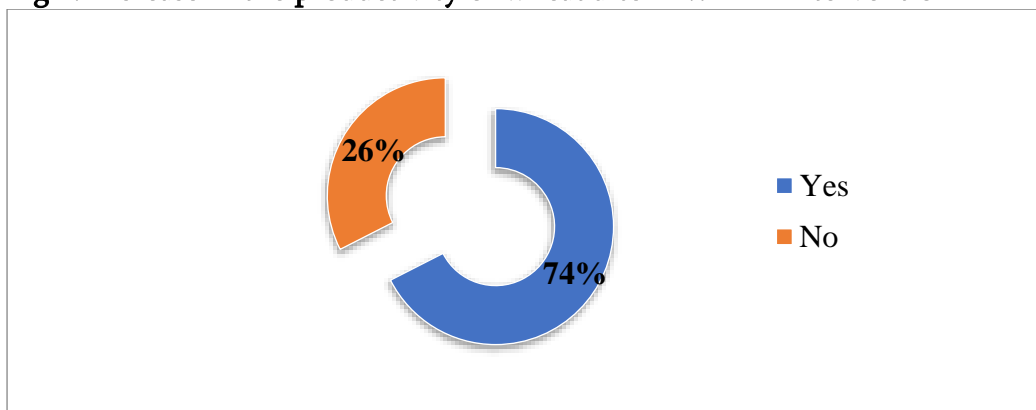
Table 1 presents descriptive statistics for variables used in predicting wheat crop productivity. For quantitative variables, it includes respondent age (ranging from 22 to 70 with a mean of 40.67), farming experience in years (ranging from 1 to 40 with

a mean of 18.12), and the number of family laborers involved in farming (ranging from 1 to 13 with a mean of 4). The table also outlines qualitative variables like educational qualifications, water availability, membership in community organizations (CO) formed by FWRDP, access to credit, access to agricultural extension services, and land tenancy. The proportions of different categories for each qualitative variable are provided.

Increase in the productivity of wheat crop

The data in Fig. 2 shows that 74 percent of the respondents answered "yes" to the question of whether there has been an increase in productivity for wheat after the FWRDP intervention, while 26 percent replied in "no". The results suggest that a majority of the respondents reported an increase in productivity for wheat after the FWRDP intervention i.e., on-farm water management.

Fig 2: Increase in the productivity of wheat after FWRDP intervention



Source: Field Survey, 2023

Crop productivity in the study area has increased as a result of FWRDP's interventions, particularly OFWM. The implementation of irrigation schemes has provided farmers with a more reliable and efficient source of water for their crops, leading to increased yields. In addition, the training provided to community organizations has helped farmers to learn about new techniques for improving productivity, such as improved seed selection, crop rotation, and pest management. This knowledge has helped farmers to produce higher quality crops and obtain better prices for their products in the market. Community-based organizations (CBOs) played an essential role in developing irrigation channels, leading to increased crop yield. OFWM, a key aspect of CBO performance, significantly contributed to enhancing water courses, positively impacting farming activities and improving the irrigation system's convenience (Khan et al., 2021). In general, the FWRDP's interventions have contributed to improving the economic conditions of the farmers in the study area by increasing their crop yields and profitability. The "before and after" scenario of wheat crop production per unit is given below in Table 2.

Table 2: Wheat productivity before and after OFWM

Yield (Mounds per Kanal)	Before	After
0-3	71 (59)	12 (10)
4-6	45 (38)	100 (83)

7 or ABOVE	4 (3)	8 (7)
Total	120 (100)	120 (100)

Source: Field Survey, 2023

Figures in parentheses show percentages

Note: 1 Jareb = 4 Kanals = 0.2 hectares (Jan, 2020)

Tables 2 shows the yield of wheat crop before and after the execution of OFWM by FWRDP. In Table 2 provides a detailed view of how wheat productivity changed before and after the implementation of On-Farm Water Management (OFWM). Initially, 59% of farmers had low yields (0-3 mounds per kanal), but after OFWM, only 10% faced low yields. For those with moderate yields (4-6 mounds per kanal), the percentage increased significantly from 38% to 83%. Additionally, the percentage of farmers achieving high yields (7 or above mounds per kanal) increased from 3% to 7%.

The data suggests that how well FWRDP interventions worked to accomplish their goals. Prior the interventions, the majority of farmers yielded low wheat, indicating a failure to fully utilize the agricultural potential of their land. It appears that the interventions have improved crop productivity by reducing important constraints, especially inadequate water access. Conserving and maximizing the use of water in agriculture requires efficient management of the water resources on the farm. In order to achieve sustainable water utilization and ultimately increase agricultural productivity (Khadr., 2017).

Empirical Results

A binary logistic regression model was used to investigate how wheat productivity was affected by on-farm water management. The dependent variable in the analysis was wheat productivity, while the independent variables included the farmer's age, farming experience, education level, the presence of a working member, the availability of irrigation water, membership in community organizations (COs), the ability to obtain agricultural credit, the availability of extension services, and land tenancy.

Table 2: Results of binary logistics model of OFWM on the productivity of wheat crop

Productivity of Wheat Crop	β	S.E.	Wald	Sig.	Exp(β)
Age of the farmer	.158	.061	6.707	.010	1.171
Farming experience	-.280	.078	12.828	.000	.756
Education Level					
Primary/Middle (1)	1.327	1.275	1.082	.298	3.769
Metric (2)	.627	1.215	.266	.606	1.872
Intermediate (3)	1.802	1.498	1.447	.229	6.061
Graduate and above (4)	-.088	2.221	.002	.968	.916
Working Member	-.688	.246	7.803	.005	.503

Water availability	1.943	.743	6.835	.009	6.980
CO Membership	2.373	.771	9.481	.002	10.724
Access to Credit	1.111	1.427	.607	.436	3.039
Access to Agricultural extension	.131	.782	.028	.867	1.140
Land Tenancy					
Tenancy Owner (1)	2.231	1.697	1.728	.189	9.309
Tenancy Owner Cum Tenant (2)	1.688	1.709	.976	.323	5.411
Constant	-6.572	2.791	5.545	.019	.001
No of observation	= 120				
-2 log likelihood	= 64.588				
R ²	= .674				
p-Value	=0.005				

Binary logistic estimates of the odds ratios associated with the variable linked with the productivity of the wheat crop are given in Table 2. The table shows the effects of explanatory variables on the productivity of wheat crop.

Table 2 shows the variable age of the farmer odds ratio is 1.171, indicating that for every one-unit increase in the age of the farmer, the odds of wheat crop productivity increase by a factor of 1.171. This suggests that older farmers tend to have higher odds of achieving productive wheat crops. The human capital theory suggests an inverse relationship between age and technology adoption, stating that younger individuals are more likely to adopt new technologies (Sidibé, 2005). The corresponding p-value of 0.010 ($p < 0.05$) suggests that the relationship between age and crop productivity is statistically significant. In other words, age is a significant predictor of wheat crop productivity, independent of other factors considered in the model.

Table 2 shows the odds ratio for farming experience is 0.756, meaning that for every one-unit increase in farming experience, the odds of wheat crop productivity decrease by a factor of 0.756. This indicates that more experienced farmers have lower odds of achieving productive wheat crops. The associated p-value of 0.000 ($p < 0.05$) suggests that the relationship between farming experience and crop productivity is statistically significant. Hence, farming experience is a significant predictor of wheat crop productivity. The results presented in this study align with the findings of (Wang, 2010) who reported that Tobit regression analysis revealed several factors that positively influence the degree of irrigation water efficiency. These factors include the age of the farmer, experience, income level, education level, and the size of the farm. The findings suggest that as farmers grow older, their level of irrigation water efficiency tends to increase.

In the same way, education levels are associated with improved irrigation water efficiency. The table 2 shows that the odds ratios represent the comparison of each education level category to a reference category, the odds ratio of 3.769 indicates

that farmers with a primary/middle education level have 3.769 times higher odds of achieving productive wheat crops compared to those with no formal education. However, the corresponding p-value of 0.298 ($p > 0.05$) suggests that this relationship is not statistically significant. Therefore, while there is an observed increase in the odds of crop productivity, it may not be considered statistically reliable. The odds ratio of 1.872 implies that farmers with a metric education level have 1.872 times higher odds of achieving productive wheat crops compared to those with no formal education. However, the associated p-value of 0.606 ($p > 0.05$) indicates that this relationship is not statistically significant. Thus, the evidence for the impact of metric education on crop productivity is weak. The odds ratio of 6.061 suggests that farmers with an intermediate education level have 6.061 times higher odds of achieving productive wheat crops compared to those with no formal education. However, the p-value of 0.229 ($p > 0.05$) suggests that this relationship is not statistically significant. Therefore, although there is a notable increase in the odds of crop productivity, it may not be considered statistically reliable. The odds ratio of 0.916 suggests that farmers with a graduate and above education level have slightly lower odds of achieving productive wheat crops compared to those with no formal education. The associated p-value of 0.968 ($p > 0.05$) indicates that this relationship is not statistically significant. Hence, the evidence does not support a significant impact of graduate and above education on crop productivity. Nevertheless, the outcomes differ from those of Eric et al (2014) and Ninh, (2021), who found that agriculture output is positively impacted by education, indicating that policies aimed at enhancing education in rural areas can greatly increase income and promote long-term agricultural and economic development in Vietnam and Ghana, respectively.

Table 2 depicts the odds ratio for having a working member in agriculture is 0.503, indicating that farmers with a working member have 0.503 times the odds of achieving productive wheat crops compared to those without a working member. The p-value of 0.005 ($p < 0.05$) suggests that this relationship is statistically significant. Therefore, having a working member has a significant association with agricultural crops productivity and family labor or working members proves more productive than hired labor (Chowdhury, 2016). Similarly, the odds ratio of 6.980 indicates that for every unit increase in water availability, the odds of achieving productive wheat crops increase by a factor of 6.980. The corresponding p-value of 0.009 ($p < 0.05$) suggests that this relationship is statistically significant. Sufficient water availability is positively associated with increased wheat crop productivity (Chandio et al., 2016).

The odds ratio of 10.724 suggests that farmers who are members of a community organization have 10.724 times higher odds of achieving productive wheat crops compared to non-members. The p-value of 0.002 ($p < 0.05$) indicates that this relationship is statistically significant. Local community organizations provide assistance to farmers through collaborative efforts, information sharing, and availability of support. They assist farmers, promote cooperation, and promote sustainable agriculture as an alternative to depending on traditional extension services (Katung and Akankwasa, 2008). CO membership is a significant predictor of wheat

crop productivity. Community-based organizations (CBOs) play important role in agricultural development, contributing to crop productivity and overall agricultural development (Matthews et al., 2009). Furthermore, the odds ratio of 3.039 implies that farmers with access to credit have 3.039 times higher odds of achieving productive wheat crops compared to those without access. However, the p-value of 0.436 ($p > 0.05$) indicates that this relationship is not statistically significant. Thus, the evidence for the impact of credit access on crop productivity is weak. Crop output can increase with agricultural credit, but only if it is not misused (Chaiya et al., 2023). Most rural farmers in Pakistan face financial constraints, impacting agriculture production. To address this, providing agriculture credits to marginalized farmers is vital for purchasing inputs and adopting modern technology (Chandio et al., 2017).

As per Table 2, the odds ratio of 1.140 suggests that farmers with access to agricultural extension services have 1.140 times higher odds of achieving productive wheat crops compared to those without access. However, the p-value of 0.867 ($p > 0.05$) indicates that this relationship is not statistically significant. Hence, the evidence does not support a significant impact of access to agricultural extension on crop productivity. Agricultural extension services primarily benefit larger-scale farmers, while smaller-scale farmers encounter challenges in accessing these valuable services (Ali and Rahut, 2013). The low production approach to agriculture can be upgraded to a higher sustainable productivity level by strengthening farmers' capacity to use the newest technologies, advocating for them, and spreading and extending information about innovative practices in a timely manner (David and Samuel, 2014).

Table 2 shows that the odds ratio of 9.309 indicates that farmers who own their land have 9.309 times higher odds of achieving productive wheat crops compared to tenant farmers. However, the p-value of 0.189 ($p > 0.05$) suggests that this relationship is not statistically significant, similarly the odds ratio of 5.411 suggests that farmers who are both landowners and tenants have 5.411 times higher odds of achieving productive wheat crops compared to tenant farmers. However, the p-value of 0.323 ($p > 0.05$) indicates that this relationship is not statistically significant. Thus, the evidence does not support a significant impact of owner cum tenant land tenancy on crop productivity. The productivity of agriculture is greatly impacted by land tenancy, as landowners are more likely to make long-term investments like soil conservation and irrigation, which raises yields. Productivity-boosting measures are given priority by owner-cultivators in secure tenancy countries such as Pakistan, where the output per hectare is highest on owner-cultivated land and lowest on sharecropping tenancy (Ali et al., 2012).

CONCLUSION

The study looks into how wheat productivity is affected by the FATA Water Resources Development Project (FWRDP), particularly with regard to On-Farm Water Management (OFWM) practices. Descriptive statistics offer a comprehensive overview of the factors that affect the productivity of wheat crops. The substantial increase in wheat productivity following the FWRDP intervention is evidence to the

project's success. This improvement can be attributed to enhanced water access, efficient irrigation practices, and knowledge dissemination through community organizations. These factors have resulted in a significant shift in productivity level of the wheat crop, demonstrating the effectiveness of FWRDP in addressing constraints. Binary logistic regression results highlight key predictor including farmer age, farming experience, primary/middle education, working member presence, water availability, CO membership, and credit access, positively impacting wheat productivity. Landownership emerges as crucial, significantly associated with higher odds of productive wheat crops. In summary, the study underlines the multilayered nature of factors influencing wheat productivity. FWRDP's interventions, particularly OFWM, have played a key role in improving wheat crop yield, addressing critical constraints, and enhancing the economic conditions of farmers. The findings emphasize the importance of specific actions and strategies, community engagement, and secure land tenure for sustainable agricultural development in the study area. This study's scope is confined to a single newly merged district to Khyber Pakhtunkhwa. Future research should expand its geographical coverage and engage larger sample sizes to enhance the representativeness and comprehensiveness of the findings.

Novelty of the study

The study explores the connection between water management practices on individual farms and wheat productivity by using quantitative techniques in District Bajaur, an area that mostly uses traditional irrigation systems. The research shows how water management methods can significantly increase crop yields and promote sustainable agriculture.

REFERENCES

- Ahmad F. (2009) Food security in Pakistan. *Pak. J. Agri. Sci* 46:83-89.
- Ahmed, E., Sulaiman, J., & Mohd, S. (2011). Wheat production and economics. *American Journal of Agricultural and Biological Sciences*, 6(3), 332-338.
- Ali M., Akram M.M., Silverman E., Habib H.U., Mohsan M., Ahmad M., Rehman S. (2022) On Farm Water Management in Pakistan-An Overview. *Int J Water Res Environ* 11:52-56.
- Ali, A., & Rahut, D. B. (2013). Impact of agricultural extension services on technology adoption and crops yield: Empirical evidence from Pakistan. *Asian Journal of Agriculture and Rural Development*, 3(393-2016-23855), 801-812.
- Ali, A., Abdulai, A., & Goetz, R. (2012). Impacts of tenancy arrangements on investment and efficiency: evidence from Pakistan. *Agricultural Economics*, 43, 85-97.
- Ali, A., Rahut, D. B., & Mottaleb, K. A. (2018). Improved water-management practices and their impact on food security and poverty: empirical evidence from rural Pakistan. *Water Policy*, 20(4), 692-711.
- Ali, M., Akram, M. M., Silverman, E., Habib, H. U., Mohsan, M., Ahmad, M., &

- Rehman, S. U. (2022). On Farm Water Management in Pakistan–An Overview. *Int J Water Res Environ*, 11(3), 52-56.
- Bakhsh, A., Rizwan, M., Ahmad, N., & Chauhdary, J. N. (2016, November). Improved on-farm water management practices for major crops in Pakistan. In *Proceedings of 2nd World Irrigation Forum (WIF2)*, W (Vol. 1, No. 07, pp. 6-8).
- Boretti, A., & Rosa, L. (2019). Reassessing the projections of the world water development report. *NPJ Clean Water*, 2(1), 15.
- Chaiya, C., Sikandar, S., Pinthong, P., Saqib, S. E., & Ali, N. (2023). The Impact of Formal Agricultural Credit on Farm Productivity and Its Utilization in Khyber Pakhtunkhwa, Pakistan. *Sustainability*, 15(2), 1217.
- Chandio A.A., Magsi H., Rehman A., Sahito J.G.M. (2017) Types, sources and importance of agricultural credits in Pakistan. *Journal of Applied Environmental and Biological Sciences* 7:144-149.
- Chandio, A. A., Jiang, Y., Joyo, M. A., & Rehman, A. (2016). Impact of area under cultivation, water availability, credit disbursement, and fertilizer off-take on wheat production in Pakistan. *Journal of Applied Environmental and Biological Sciences*, 6(10), 10-18.
- Chartzoulakis, K., & Bertaki, M. (2015). Sustainable water management in agriculture under climate change. *Agriculture and Agricultural Science Procedia*, 4, 88-98.
- Chaudhry A.M. (2017) Improving on-farm water use efficiency: Role of collective action in irrigation management. *Water Resources and Economics*.
- Chowdhury, N. T. (2016). The relative efficiency of hired and family labour in Bangladesh agriculture. *Journal of International Development*, 28(7), 1075-1091.
- David M.M., Samuel H.S. (2014) The role of agriculture extension in the 21 century: Reflections from Africa. *International Journal of Agricultural Extension* 2:89-93.
- Eric, O. O., Prince, A. A., & Elfreda, A. N. A. (2014). Effects of education on the agricultural productivity of farmers in the Offinso Municipality. *Int. J. Dev. Res*, 4(9), 1951-1960.
- FWRDP (FATA Water Resources Development Project), 2022. Project Implementation Unit, FWRDP, District Bajaur
- GoP (Government of Pakistan). (2017). Pakistan Bureau of Statistics. Retrieved from <https://www.pbs.gov.pk/census-2017-district-wise>
- Hussain I., Hanjra M.A. (2003) Does irrigation water matter for rural poverty alleviation?: Evidence from South and South-East Asia.
- Jan, I. (2020). Socio-economic determinants of farmers' adoption of rainwater harvesting systems in semi-arid regions of Pakistan. *Journal of Agricultural Science and Technology*, 22(2), 377-387.
- Katung, E., & Akankwasa, K. (2008, October). Community-based organizations and their effect on the adoption of agricultural technologies in Uganda: a study of

- banana (*Musa spp.*) pest management technology. In IV International Symposium on Banana: International Conference on Banana and Plantain in Africa: Harnessing International 879 (pp. 719-726).
- Khadr, M., Zeidan, B. A., & Elnmer, A. (2017). On-farm water management in the Nile Delta. *The Nile Delta*, 325-344.
- Khan A. (2015) Existing state of the farm land management and its impact on farm productivity in khyber pakhtunkhwa. *city university research journal* 5.
- Khan, F., Khan, H., Shah, M. T., Khan, N., Hassan, A. U., & Khan, N. (2021). Potential of community based organizations in irrigation channels to enhance crop production. *International Journal of Agricultural Extension*, 8(3), 225-233.
- Luqman M., Shahbaz B., Ali T., Iftikhar M. (2013) Critical analysis of rural development initiatives in Pakistan: implications for sustainable development. *Spanish Journal of Rural Development* 4.
- Matthews-Njoku, E. C., Angba, A. O., & Nwakwasi, R. N. (2009). Factors influencing role performance of community based organisations in agricultural development. *International NGO Journal*, 4(6), 313-317.
- Ninh, L. K. (2021). Economic role of education in agriculture: Evidence from rural Vietnam. *Journal of Economics and Development*, 23(1), 47-58.
- Pakistan economic survey, 2022-23. Retrieved from Finance Division https://www.finance.gov.pk › survey_2023
- Schultz, B., Thatte, C. D., & Labhsetwar, V. K. (2005). Irrigation and drainage. Main contributors to global food production. *Irrigation and Drainage: The journal of the International Commission on Irrigation and Drainage*, 54(3), 263-278.
- Sidibé, A. (2005). Farm-level adoption of soil and water conservation techniques in northern Burkina Faso. *Agricultural water management*, 71(3), 211-224.
- Sidibé, A. 2005. Farm-level Adoption of Soil and Water Conservation Techniques in Northern Burkina Faso. *Agric. Water Manage.*, 71(3): 211-224.
- Ul Hasan, F., Fatima, B., & Heaney-Mustafa, S. (2021). A critique of successful elements of existing on-farm irrigation water management initiatives in Pakistan. *Agricultural Water Management*, 244, 106598.
- Wang, X. Y. (2010). Irrigation water use efficiency of farmers and its determinants: Evidence from a survey in northwestern China. *Agricultural Sciences in China*, 9(9), 1326-1337.