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The Dynamics of the Relationship Between Water Availability, Water Equity, Economic Benefits and Water User Associations' Performance: A PLS-SEM Approach

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Abstract

Water availability, water equity, farmers' participation, compliance with rules and conflicts, and water theft management are the main drivers of water user associations' (WUAs) performance. The main objective of the study was to find out the relationship between water availability, water equity, economic benefits, and WUAs' performance. This study was conducted in 2 distributaries at the Lower Chenab Canal west area water board in the district of Faisalabad, Pakistan. A multistage random sampling technique was used to collect the data from 240 farmers using a well-structured questionnaire. A PLS-SEM model was used to analyze the structural paths between water availability, water equity, economic benefits, and WUAs' performance. The measurement model by using Cronbach's alpha, rho-A, composite reliability (CR) and average variance extracted (AVE) has confirmed the internal reliability and validity of the questionnaire. Results indicate that timely water availability, less water shortage, and timely repair and maintenance were the core influencing indicators with high factor loadings (>0.70) to the water availability construct that significantly positively influencing the economic benefits($\beta=0.74$, $p=000$) and performance of WUAs ($\beta=0.34$, $p=000$). Equitable distribution of water across the farm size, location, ethnic groups, and greater fair and justice were the substantial influencing indicators with high loadings (>0.80) to the water equity construct that has positive and direct significant influence on the performance of WUAs ($\beta=0.48$, $p=000$). It has been evaluated that water availability and economic benefits had a positive and indirect impact on the WUAs performance ($\beta=0.09$, $p=000$). Besides the insights of all the drivers of performance of WUAs, the study recommended that WUAs management system still in infancy even after the decades of its establishment and establishing the parallel institutes are neither sufficient nor mandatory. Furthermore, there is a need to reconsider the inner structure of WUAs management and establishment of cohesion among all the stakeholders in decision making. There is also a need to provide trainings to farmers and WUAs officials for effective management of WUAs system.

Keywords Water availability · Water equity · Water user associations' performance · PLS-SEM · Pakistan

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1 Introduction

In South Asia, institutional weaknesses have greatly reduced efficiency in irrigation (Naseer et al. 2020), and policies have emerged in the sector that involve simply decentralizing decision-making power to farmers. These policies have produced mixed results, especially in eastern India and Pakistan (Hone et al. 2020; Senanayake et al. 2016). In cooperation with the World Bank and the Asian Development Bank, Pakistan has invested heavily in institutional irrigation management to transfer responsibilities and irrigation management (Baig et al. 2009; Razzaq et al. 2019).

In Pakistan, rural poverty is widespread, while the potential of the river Indus is still not harnessed to its potential due to improper policy and management choices. In the world's most densely populated basin, the Indus Basin Irrigation System (IBIS), a considerable portion of the population is poor and heavily dependent on agriculture and water management (Zulfiqar et al. 2017). Due to the impact of population increase and climate variability, the shortage of water resources has intensified, so a strong irrigation system supported by strong management institutions is essential (Gandhi and Johnson 2020).

In the period of the green revolution in the last century, from 1960 to 1970 and onward, the poor performance of irrigation systems has been considered a high-priority agenda item at the national and international levels (Ghumman et al. 2014). Despite substantial investment in repairing the infrastructure of irrigation systems, the performance of inefficient irrigation systems has declined (Mekonnen and Hoekstra 2016). Due to the poor performance of the heavily subsidized irrigation system, national and international agencies have changed their strategies, arguing that institutional issues limit Pakistan's overall irrigation management (Akhtar and Cepiku 2013).

Participatory Irrigation Management (PIM) is recognized as an effective tool for irrigation water management in the developing world (Singh et al. 2014). However, PIM in Pakistan is facing various challenges in achieving its goals and objectives, including support, the will of the government, and policymakers. This reform also faces resistance from the provincial irrigation departments in the public sector, which are still too reformed. The country's reform process is struggling because of a lack of political will and the full support of the stakeholders. Despite some positive results, due to economic incentives, PIM has also led to conflicts of interest between the relevant stakeholders [i.e., farmer organizations (FOs) and public irrigation departments] (Nagrah et al. 2016). Weak institutions allow the use of scarce resources in relatively prolific areas/pursuits, thereby exacerbating biophysical challenges (Ahmad et al. 2020). This reduces agricultural production and plunges the rural population into poverty. In contrast, effective water management institutions can provide buffers for bio-physical challenges by encouraging the use of water in the most productive ways and by sending signals of adaptation when scarcity is threatened (Crase and Gandhi 2009).

Water availability is the key driver of agricultural land development (Vafaei et al. 2021), poverty alleviation, food production sufficiency (Shahbaz et al. 2022) and adaptive capability to climate variability in low to medium income countries (Uysal and Atış 2010). The effective use and management of irrigation water are playing a key role in minimizing the effects of water scarcity (Riaz and Ashfaq 2019) as a consequence of climate change and global warming and also making farms' production systems efficient (Güvercin and Boz 2003). The low efficiency in farms' production is on account of water scarcity as a consequence of ineffective irrigation management (Calzadilla et al. 2011). Water equity is the key component of sustainable economic development (Aruna et al. 2012) in areas of high dependence on irrigation water for agricultural productivity and livelihoods (Srivastav et al. 2021). It ensures the equitable distribution of water resources across the different farms' sizes, locations, and ethnic groups. Greater fairness and justice and effective governance in irrigation upgrades ensure water equity to farmers (Ahmad et al. 2020). Water equity and availability lead to greater crop diversification (Shahbaz et al. 2017; Razzaq et al. 2019), high yields and income, and also minimize the water scarcity risk as a result of climate change (Anser et al. 2020).

The efficiency of the irrigation system depends on the legal farmers' participation, socio-economic indicators, and timely repair and management of irrigation structures (Yercan et al. 2009). Farmers' participation, compliance with rules (Wang et al. 2010), conflicts management, share of water charges, and repair and maintenance (Muchara et al. 2014) indicators enhance the water user associations' (WUAs') performance. Water availability and water equity (Manero and Wheeler 2022) have a positive association with the WUAs' performance in collectively managed irrigation systems. Crop diversification, higher yields, and income are the main economic benefits as a result of effective irrigation management (Riaz and Ashfaq 2019). Economic benefits and effective management of irrigation systems by WUAs have a positive association. Water resource distribution by WUAs boosts the efficiency and performance of collectively managed irrigation systems (Kazbekov et al. 2009). Farms' profitability, higher productivity, and efficiency have a decisive role in the performance of WUAs (Abdelhafidh et al. 2017).

However, an extensive body of literature showed that no theoretical framework still has been developed to assess the performance of WUAs and their relations with other influencing constructs. To fill the gap, this study proposes a detailed theoretical framework to analyze the influencing factors of water availability, water equity, economic benefits, and the performance of WUAs; and also assess the dynamics of the relationship between them.

2 Materials and Methods

2.1 Study Area, Sampling and Sample Size Determination

Pakistan's economy is an agricultural one, providing livelihood to 60–70% of the country's population. Punjab is the most populous province in Pakistan, contributing 20% to the economy's Gross Domestic Product (GDP) (Shahbaz et al. 2017). It has fertile land with favorable climatic conditions and the world's largest irrigation system (Riaz and Ashfaq 2019). Faisalabad is the 3rd most populous city in Punjab after Karachi and Lahore, the main hub of the textile industry in Pakistan (Farooq and Shakoor 2013). It contributes 5% to the economy's GDP, having a 21% share of agriculture (Haq et al. 2020). The Lower Chenab Canal (LCC) east and west are the two main sources of irrigation in Faisalabad and surroundings, irrigate 1.195 million acres of land in Faisalabad (Riaz and Ashfaq 2019). The LCC (East) and West were constructed in 1892, branching from river Chenab at Khanki head works and Qadrabad heads works, respectively (Baig et al. 2009). The Khanki and Qadrabad head works have 8 and 9 million cusec of drainage water, respectively. The LCC (east) circle is being selected because it was the one of the canal where first time irrigation reforms were implemented. This study was conducted in two distributaries of the LCC west circle Area Water Board (AWB), having 67 Farmer Organizations (FOs), 175 water course level Khal Panchayats (KPs), and 2617 outlets. The sample size is determined by using Cochran's formula, given as;

$$n_0 = \frac{Z^2 \times p \times q}{e^2}$$

where

n_0 = sample size

Z = confidence level

p = proportion of population

q = 1-p

e = precision level (margin of error).

The sample size of 240 farmers was obtained at a 95% level of confidence, a 50% population proportion (total variability), and a 6% precision level or margin of error. A multi-stage random sampling technique was used to collect the data from 240 farmers using a structured questionnaire.

2.2 Analytical Procedure

Recently, Structural Equation Modelling (SEM) has emerged as a new application (Sarkar et al. 2021) and has increased its applications substantially due to its better ability to assess the constructs' reliability and validity and test the structural relationship (Wang et al. 2022). There are two main techniques of SEM, i.e., Co-variance based (CB) and variance based Partial Least Square (PLS) based SEM (Shahzadi et al. 2021). CB-SEM is used for confirmation of the developed theories (Mikalef et al. 2021). However, PLS-SEM is a prediction-oriented technique used in explanatory research (casual relationships) and also in confirmatory research (Bhatti et al. 2020). The CB-SEM model (common factor model) is used to estimate the model parameters which minimize the difference between the estimated and observed sample co-variance matrix (Taheri et al. 2019). Whereas, the PLS-SEM model (a composite model) is used to maximize the response variable variance. The CB-SEM model is a parametric method which provides the estimates with a significance level. However, PLS-SEM is a non-parametric approach which provides only estimates, not significance level but a complete boost trapping at 5000 subsamples is being used for measuring the standard errors that provide the significance testing (Vafaei et al. 2021). SEM can be employed on minimum 100 or 10 multiple of indicators of sample size (Rehman Khan and Yu 2021). While, for this study, data were collected from 240 farmers operated under the WUAs on Likert scale 1–5. This study used the PLS-SEM model to measure the paths between water availability, water equity, economic benefits, and WUA performance and also evaluated the relationships between the latent variables and indicators. This study used the reflective form of PLS-SEM as shown in Fig. 1.

2.2.1 Reliability and Validity

Reliability and validity are the two key concepts to measure the quality of a research through consistency and accuracy of measure (Hair et al. 2017). Nosair et al. (2022) used the artificial intelligence methods including logistic regression and Gaussian process regression (GPR), to ensure the reliability and robustness of the regression model. The reliability and validity of the used scale in the study were assessed through confirmatory factor analysis by using the PLS-SEM modelling method. The assessment of the reliability of the scale was reported by the Cronbach's alpha, composite reliability, rho-A, and factors loadings. While, convergent validity for this scale was assessed through the average variance

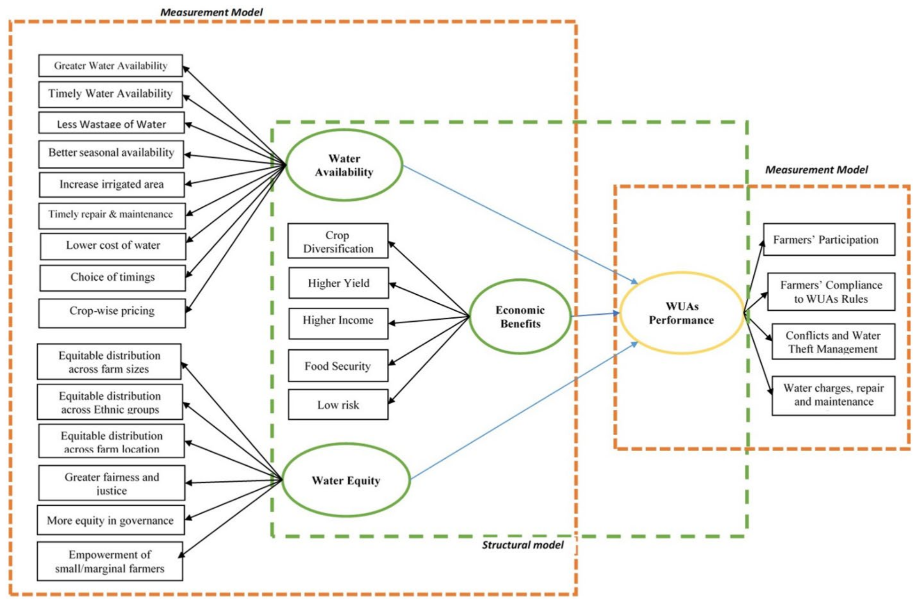

Fig. 1 A Conceptual Framework of dynamics of relationship between water availability, water equity, and economic benefits and WUAs performance

extracted (AVE) values. In this study, discriminant validity was determined through the Fornell and Larcker criterion.

2.2.2 Measurement Model

The SEM technique consists of two statistical approaches, i.e., explanatory factor analysis and structural path analysis, used to assess the inner (structural) model and outer models (measurement model) (Vafaei et al. 2021). A structural model represents the structural paths between constructs, whereas a measurement model represents the relationship between latent variables and linked indicators (Hourneaux et al. 2018). The measurement model of this study consists of water availability, water equity, economic benefits, and WUAs' performance constructs and their indicators. Water availability encompasses the supply, demand, and access of irrigation water to farmers at farm level (Bekchanov et al. 2010). The water availability construct consists of greater water availability; timely water availability; less wastage of water; better availability across the seasons; increased irrigated area; timely repair and maintenance; low cost of water; choice of timings and crop-wise pricing indicators (Ahmad et al. 2021; Murtinho et al. 2013; Zhang et al. 2013). Water equity means equitable distribution of irrigation water to the farmers without discriminating against caste, location, and position in the village setup (Aruna et al. 2012). The main indicators of water equity are equitable distribution of irrigation water across farm sizes, ethnic groups, farm location, greater fairness and justice, more equity in governance, and empowerment of small farmers (Balasubramanya et al. 2016; Srinivasan and Kulkarni 2014). Crop diversification, higher yield, higher income, food security, and low risk indicators define the economic benefits construct. These main indicators are mainly influencing the economic benefits. WUAs performance constructs consist of farmers' participation, compliance with rules, effective conflicts and water theft management, water charges, repair and maintenance share of farmers as shown in Fig. 1.

2.2.3 Structural Model

A structural model, also known as an inner model, is used to measure the structural paths between the constructs (Wang et al. 2022). There are 2 indirect paths and 5 direct paths to measure the relationships between the constructs as shown in Fig. 1.

The Main Drivers of WUAs Performance Good governance and compliance with the rules by all stakeholders are the key drivers of effective management of any institution or system. Compliance with the rules in reformed water institutions system not only decrease the transaction cost but also improves the efficiency (Gandhi and Johnson 2019). WUAs are the institutions, composed of farmers and their leaders and the technical staff provided by the public irrigation departments. So, the farmers' participation is also a key influencing factor in managing and upgrading the irrigation system (Mochalova 2014). The main goals of the reformed irrigation system are to increase the water availability and equitable distribute the water to all farmers. However, the share in water charges and managing and upgrading of irrigation system hinders the up-gradation and improvement of irrigation structures operations (Ahmad et al. 2020). The water theft and conflict management among the farmers at the head reach farmers lower the water supply at the tail reach farmers (Riaz and Ashfaq 2019). The performance of any organization depends on the level of fulfillment of its objectives. Therefore, the key drivers of WUAs performance has been developed by considering the all primary objectives of its establishment.

Dynamics of Relationship Between Water Availability, Equity, Economic Benefits and Wuas Performance While the water availability construct (latent variable) depends on the multi-observed factors i.e. timely, greater water availability, less shortage of water, timely repair and maintenance, increased irrigated area, low and crop wise pricing that makes the farms more productive and economical viable (Mekonnen et al. 2015; Gandhi and Johnson 2019). However, the equitable distribution of water resources among the farmers without discriminating them on the basis of farm size, location, ethnicity and also greater fairness and justice, and give representation to all type of farmers defines the water equity constructs. The higher and equitable water availability to all farmers leads to greater crop diversification, higher yield and income, food security and make the farms less prone to any risk and uncertainty. The higher economic benefits develop the interest of farmers to be compliance with rules, participate in activities and make contribution to the share in water charges and repair and maintenance of irrigation structures that leads to effective and better performance of WUAs. The observable variables for this study were selected considering the earlier studies conducted is this subject (Gandhi and Johnson 2019; Ahmad et al. 2020; Crase 2020) as well as concerning agricultural institutions and WUAs officials in the research area. Main data were collected in five points Likert scale. Therefore, based on the literature and theory of institutional performance, the hypotheses and relationships related to constructs are defined below:

H1: Water availability significantly influences the economic benefits.
H2: Water equity and economic benefits are significantly associated.
H3: Economic benefits and WUA performance are significantly interconnected.

H4: Water availability is significantly influencing the WUAs' performance.
H5: Water equity is significantly influencing the WUAs' performance.
H6: Water availability influences the economic benefits that have an association with WUA performance.
H7: Water equity influences the economic benefits that have an association with WUA performance.

3 Results

3.1 Socio-Economic and Farms' Characteristics of Participants

This section describes the socio-economic and farm characteristics of respondents in the study area. Socio-economic characteristics help to understand the social standing and class of farmers in society. Rapid changes in the socio-economic characteristics (Education, age, family size and income level) substantially reshaping the irrigation management in south Asian region. Results of socio-economic and farms' characteristics are presented in Table 1. The mean age of the farmers was about 46 years old, with mean middle formal schooling. More than half of family members were up to sixty years old and one-fourth were less than eighteen years old. The family members were about equally distributed in terms of male and female. Farming is the main source of income in rural economies like Pakistan's. There were one-third of the farmers had off-farm income source and less than one-third of the family members involved in agriculture. The majority of the farmers

Table 1 Socio-economics and farms' characteristics of participants

Socio-economics and farms' characteristics		Mean	Std. Dev.
Age (Years)		46.60	13.12
Education (Years)		7.53	4.34
Family members		7.04	3.10
By age	< 18 Years	2.17	1.81
	18–60 Years	4.28	2.24
	> 60 Years	0.58	.828
By gender	Male	3.83	1.89
	Female	3.21	1.84
By occupation	Agriculture	1.47	0.88
	Non-agriculture	0.48	0.91
Off-farm income (1 = Yes)		0.32	0.46
Owned area (Ha)		3.20	3.10
Leased-in (Ha)		0.36	1.01
Leased out (Ha)		0.02	0.23
Operational land-holding (Ha)		3.58	3.23
Irrigated area through canal (Ha)		2.88	2.96
Irrigated area through tube-well (Ha)		0.70	4.41
Irrigation charges (PKR/Year)		1195.71	1233.71
Distance from canal to farm (Km)		1.27	0.86

belonged to small farmers, had less than four hectares of operational land holdings. The third-fourth of the operational land holding is being irrigated through the canal and one-fourth through private tube-wells. The majority of the farmers had their operational holdings in tail-reaches, with a mean 1.27 km distance between canal and farm.

3.2 Farmers' Perception and Knowledge about WUAs Functions and Decisions

Table 2 represents the assessment of farmers' perception and knowledge about the functions and decisions of WUAs regarding planning, water schedule, fee collection, repair, maintenance, and conflict management in the study area. Planning is considered the initial and most important step of any decision and restricts the overlapping of responsibilities. Effective planning leads to effective management and improves the co-ordination in any system. More than half of the farmers had the perception that planning for capital investment in irrigation structures was done by the government (irrigation department) and less than half by the WUAs. The implementation of any decision or plan on the ground needs the provision of resources for investment. Provision of funds agency in collectively irrigation management differs in situation of repair, maintenance and development of new structures. More than a third-fourth of the farmers agreed that the provision of the funds for investment should be provided by the irrigation department, and more than 16% agreed with WUAs. The two-third farmers were agreed that decision of planning and actual release of water is being done by the irrigation department. However, more than two-thirds of the farmers agreed that the decision on the distribution of water among the farmers was the responsibility of WUAs. All of the farmers agreed that the collection of water charges was the responsibility of the WUAs. More than half of the farmers agreed that the decision of maintenance, provision of resources, and implementation of repair and maintenance should be managed by the WUAs in the study area. The two-thirds of the farmers agreed that the monitoring of the use of the water and stopping misuse of water had been managed

Table 2 Farmers' perception and knowledge about WUAs functions and decisions (%)

Decision/ Activity	Govt.	WUAs	Indiv. Farmers
Planning for capital investment in irrigation structures	54.1	45.9	-
Provision of resources for investment	82.4	16.7	0.90
Assessment of water availability	29.9	66.7	3.5
Planning/ scheduling the release of water	71.1	28.9	-
Actual release of water	79.6	20.4	-
Distribution of water among farmers	8.8	91.2	-
Fixing price of water paid to government	25.2	74.8	-
Collection of fees from farmers	-	100	-
Decision on maintenance/ repair requirement	31.1	58.5	10.4
Provide resources for maintenance/ repair	29.6	64.2	6.3
Implementation of maintenance/ repair	37.7	58.2	4.1
Repair and maintenance after a flood event	34	19.5	46.5
Monitoring use of water	8.2	78.6	13.2
Stopping misuse/ waste	14.5	75.8	9.7
Action on misusers	77.4	12.3	10.4

by the WUAs. However, the majority of the farmers agreed that the action against the misusers of water was the responsibility of the government (irrigation department).

3.3 Comparison of Water Availability on Different Farms Location Before and After WUA

Results of comparative analysis of water availability across farms' locations over the years indicated that the water availability among the head, middle, and tail-reach farmers was significantly different. It shows that the tail-reach farmers had less water availability than the middle and head-reach farmers, but the water availability has significantly improved over the years. The water availability before the WUAs management was about 33 turns in the head-reach, 31 in the middle-reach and about 24 turns annually in the tail-reach farmers, as shown in Table 3.

3.4 Assessment of Measurement Model

PLS-SEM is a multidimensional analysis, less sensitive to sample size and data normalization. It has two types of models, i.e., measurement model and structural model. The first step of the model is to assess the goodness of fit of the measurement model. The model is said to be goodness to fit, if it has no multicollinearity problem, kurtosis and skewness values between ± 3 and a VIF value of all indicators less than 3. The values of kurtosis and skewness values were ranged between ± 3 and VIF values were also less than 3, indicating that there was no multicollinearity problem. Results indicate that the factor loadings of all factors were above 0.70, indicating that more than 70% of the variation has been explained by the indicator variance. The Cronbach's alpha, rho-A, and composite reliability (CR) were also above the critical values, which showed that the model was also internally reliable (Table 4). The average variance extracted (AVE) values were also above 0.50, which indicates that constructs were also valid and explained the variance of items as shown in Table 5. As a result, internal reliability has been developed.

Discriminant validity explains the distinction of constructs from other constructs in inner and outer models. According to the Fornell and Larcker criterion (1981), the

Table 3 Comparison of water availability on different farms location before and after WUA

Water availability situation (No. of annual irrigation turns)	Farm Location		Difference
	Head reach	Middle reach	
Before WUA	32.80 (1.98)	30.80 (4.36)	2.01***
After WUA	37.10 (1.96)	35.34 (2.40)	1.76***
	Head reach	Tail reach	
Before WUA	32.80 (1.98)	24.14 (10.54)	8.38***
After WUA	37.10 (1.96)	29.88 (6.87)	7.21***
	Middle Reach	Tail Reach	
Before WUA	30.80 (4.36)	24.14 (10.54)	6.37***
After WUA	35.34 (2.40)	29.88 (6.87)	5.45***

***shows a statistical significant difference at 1%. The values in parenthesis are standard deviations

Table 4 Indicators loadings, reliability and convergent validity

Variables	^	α	rho-A	CR	AVE
Water Availability and Use of Water		0.908	0.910	0.925	0.577
Greater water availability	0.728				
Timely water availability	0.798				
Less wastage of water	0.773				
Better availability across seasons	0.750				
Increase in irrigated area	0.730				
Better and timely maintenance and repairs	0.780				
Lower cost of water	0.756				
Choice of timings	0.712				
Crop-wise pricing of water	0.805				
Water Equity		0.932	0.932	0.946	0.746
More equitable distribution across farm sizes	0.886				
More equitable distribution across social/ethnic groups	0.844				
More equitable distribution across head and tail reach	0.871				
More equity in water governance/ management	0.841				
Greater fairness & justice	0.881				
Greater involvement & empowerment of small farmers	0.858				
Economic Benefits		0.810	0.816	0.868	0.569
Crop diversification/Higher value crops	0.807				
Higher yields	0.753				
Higher income	0.727				
Food security	0.729				
Low risk	0.751				
WUAs Performance		0.883	0.885	0.920	0.741
Farmers' participation	0.837				
Farmers' compliance to WUAs rules	0.876				
Conflicts and water theft management	0.862				
Water charges, repair, and maintenance share	0.869				

Table 5 Discriminant Validity based on Fornell and Larcker criterion

	Economic Benefits	WUAs Performance	Water Equity	Water Availability
Economic Benefits	0.754			
WUAs Performance	0.690	0.861		
Water Equity	0.623	0.806	0.864	
Water Availability	0.797	0.789	0.738	0.760

diagonal values of constructs in a matrix should be greater than 0.60, which indicates that every construct is distinctive in nature. Table 6 shows that all constructs have loading values of more than 0.6, indicating that all constructs have convergent validity as shown in Table 6.

Table 6 Results of direct SEM path relationships

Hypotheses	Relationships	β	S.E	T-value	Decision
H1	Economic benefits → WUAs performance	0.12	0.052	2.30**	Accepted
H2	Water Equity → Economic Benefits	0.08	0.056	1.41	Rejected
H3	Water Equity → WUAs Performance	0.48	0.034	13.77***	Accepted
H4	Water availability → Economic Benefits	0.74	0.046	16.04***	Accepted
H5	Water availability → WUAs Performance	0.34	0.054	6.19***	Accepted

**significant at 0.05; ***0.01 level

3.5 Assessment of Structural Model

The second phase of the model is to assess the structural model. It is necessary to provide statistically reliable and valid factor loadings. The booster trapping at 5000 subsample with complete booster trapping condition and two tail test was used. Results indicate that all factor loadings were statistically valid at less than 1% level of significance, as shown in Fig. 1. It showed that water availability, water equity, and economic benefits were significantly positively associated with the WUAs' performance. However, water equity has no significant association with economic benefits, while water availability has a significant positive association with economic benefits (Table 7 and Fig. 1). The indirect relationship between water availability, economic benefits, and WUAs performance was statistically positively associated, as shown in Table 7 and Fig. 1. It has been observed that with the increasing level of water availability across the command area increases the economic benefits at farms ($\beta = 0.740$, $p = 0.000$). This implies that with higher water availability provides the more opportunities at farms to produce more diverse crops and increase livelihoods. It also assessed that water availability is directly positively influenced the WUAs performance ($\beta = 0.339$, $p = 0.000$). It shows that the timely, better water availability across the seasons and farms have direct association with WUAs performance. Results indicate that equitable distribution of water resources leads to water equity that directly positively influenced the WUAs performance ($\beta = 0.481$, $p = 0.000$). The water availability and economic benefits constructs also indirectly positively influenced the WUAs performance ($\beta = 0.089$, $p = 0.001$). This implies that the timely, better and higher water availability increases the economic benefits of agricultural farms that leads to effective performance of WUAs as a result of higher farmers participation, compliance with rules, higher contribution in water fees and maintenance funds and effective conflicts management (Fig. 2).

Table 7 Results of indirect SEM path relationships

Hypotheses	Indirect relationship	β	S.E	T-value	Decision
H6	Water Availability → Economic Benefits → WUAs Performance	0.089	0.038	2.29**	Accepted
H7	Water Equity → Economic Benefits → WUAs Performance	0.009	0.008	1.12	Rejected

**significant at 0.05

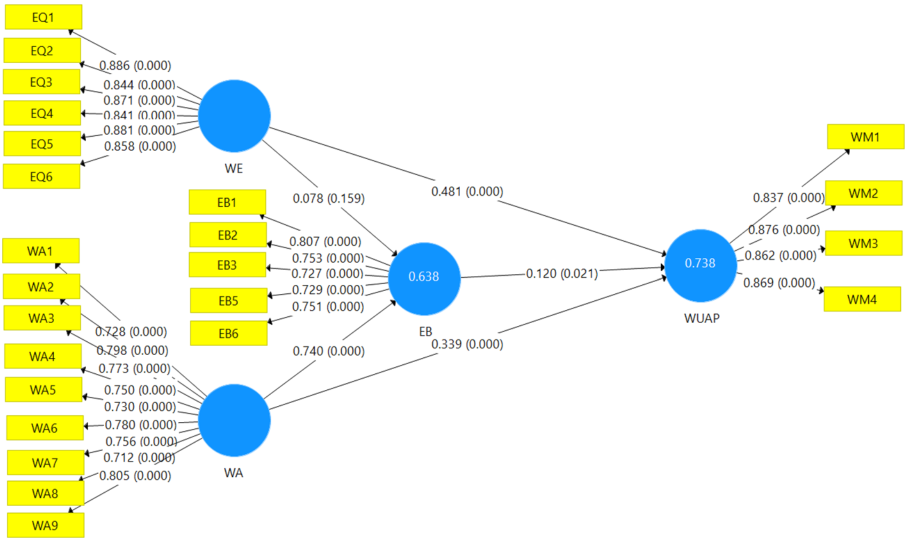

Fig. 2 Direct and indirect SEM path analysis for WUAs performance

4 Discussion

The water availability across the farms' location before and after the establishment of WUAs has improved; this may be due to the lining of the water courses, timely repair and maintenance of irrigation structures. In this study, the indicators and the framework for dynamics of relationships between water availability, water equity, economic benefits, and WUAs performance are developed, where all constructs are found feasible in the study area. The factor loadings of water availability, i.e., timely water availability, less wastage of water, and timely repair and maintenance, had a core impact with good factor loadings (> 0.70) for forecasting the water availability among the surveyed farmers. The main objectives of the WUAs' establishment were to increase the water availability, minimize the loss of water, and timely repair and maintain the irrigation structures. All six indicators of water equity, i.e., equitable water distribution across the farm sizes, location, ethnic groups, equity in water governance, greater fair and justice, better governance, and equity in farmers' involvement of small farmers, had a substantial impact on water equity constructs with factor loadings greater than 0.80. All four indicators, namely farmers' participation, compliance with rules, conflicts and theft management, water charges, and repair and maintenance share, had substantial impact on the WUAs performance construct with factor loadings of more than 0.83. The main indicator of economic benefits, i.e., crop diversification, had a greater and substantial impact on the economic benefits construct with factor loading > 0.80. This study revealed a significant positive relationship between water availability and economic benefits; water availability and WUAs performance; water equity and economic benefits; and economic benefits and WUAs performance latent variables, which are supported by Abdelhafidh et al. (2017); Vafaei et al. (2021) and Manero and Wheeler (2022). Although a positive relationship between water equity and WUAs performance was found, it was statistically not significant in the study area. Higher and timely water availability and water equity lead to more crop diversification, higher income, higher income level, and low production risk. Higher crop diversification and yields are the main drivers of economic benefits for farmers that lead to greater farmer's participation, compliance with rules, effective conflict and water theft management, and a higher share of water charges and repair and maintenance. All these indicators are significantly impacting their constructs, and all constructs are positively associated with each other.

5 Conclusion

In recent times, participatory irrigation management has emerged as an effective tool for effective irrigation management with greater water availability and equity across the farms' sizes, locations, and ethnic groups. Pakistan is the 6th most populous country in the world, with an increasing population putting pressure on food production. The water requirement has been increasing day by day, but fortunately Pakistan has the world's largest irrigation structure. The water availability at head reaches farms was significantly higher than the middle and tail reach farms before and after the WUAs reforms implementations. Moreover, the water availability at the middle and tail reach has been also increased over the time. Majority of the farmers agreed that the distribution of water among the farmers and collection of water charges were the responsibility of the WUAs. While the conflict management and action against the misusers were the responsibility of irrigation department. It has been evaluated that the higher, timely and better availability of water across the seasons defined the water availability construct and directly significantly influenced the economic benefits. The water availability and economic benefits indirectly positively influenced the performance of WUAs. The higher water availability leads to more economic benefits at farms with more diversification that ultimately incentivizes the farmers to participate in WUAs activities and compliance with rules and contributing in water charges and repair and maintenance share. Additionally, equitable distribution of water across the farms location, ethnic groups, farms sizes and greater fairness in governance leads to water equity at canal level that has significantly direct positive impact on the performance of WUAs. This study concluded that there is a positive association between water availability, water equity, economic benefits, and WUA performance. Effective water management and WUAs performance, water availability and water equity, farmers' participation, compliance with rules, effective conflict and theft management, and farmers' share in repair and maintenance should be effectively managed through encouraging the farmers and providing training to the WUAs officials.

Author Contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [Mohsin Riaz], [Muhammad Ashfaq] and [Ismet Boz]. The first draft of the manuscript was written by [Pomi Shahbaz] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Availability of Data and Materials The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing Interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abdelhafidh H, Bachta MS, Khamassi K, Chaabane R, Kharrat M, Naceur MB (2017) Effect of water users associations' financial performances on small farms' productivity. J New Sci 41

Ahmad B, Pham HD, Ashfaq M, Memon JA, Bano R, Dahri ZH, Mustafa RN, Baig IA, Naseer MAUR (2020) Impact of institutional features on the overall performance assessment of participatory irrigation management: Farmers' response from Pakistan. Water 12:497

Ahmad S, Perret SR, Imran M, Qaisrani SA (2021) Assessing the physical water availability and revenue aspect of WUAs under new governance system: Case studies of Pakistan. In Water Security in Asia (pp. 251–260). Springer, Cham

Akhtar MJU, Cepiku D (2013) Participatory irrigation management in Pakistan: Initial results of a pilot project. South Asian Water Stud 4:4–22

Anser MK, Hina T, Hameed S, Nasir MH, Ahmad I, Naseer MAUR (2020) Modeling adaptation strategies against climate change impacts in integrated rice-wheat agricultural production system of Pakistan. Int J Environ Res Public Health 17(7):2522

Aruna G, Singh DR, Kumar S, Kumar A (2012) Canal irrigation management through Water Users Associations and its impact on efficiency, Equity and reliability in water use in Tamil Nadu. Agric Econ Res Rev 25:409–419

Baig IA, Ashfaq M, Hassan H, Mushtaq K, Raza MA (2009) An analysis of irrigation reforms and their impact on rural livelihood in Punjab. Pakistan. J Agric Res 47(3)

Balasubramanya S, Buisson MC, Saikia P, MacDonald K, Aslamy S, Horbulyk T, Platonov A (2016) Impact of Water Users Associations on water and land productivity, equity and food security in Tajikistan. Baseline Tech Rep Int Water Manag Inst

Bekchanov M, Karimov A, Lamers JP (2010) Impact of water availability on land and water productivity: a temporal and spatial analysis of the case study region Khorezm. Uzbekistan Water 2(3):668–684

Bhatti A, Rehman SU, Rumman JBA (2020) Organizational capabilities mediates between organizational culture, entrepreneurial orientation, and organizational performance of SMEs in Pakistan. Entrepreneurial Bus Econ Rev 8(4):85–103

Calzadilla A, Rehdanz K, Tol RS (2011) Water scarcity and the impact of improved irrigation management: A computable general equilibrium analysis. Agric Econ 42(3):305–323

Crase L (2020) Using applied economics to study participatory irrigation institutions and their impact in South Asia. Water 12(7):2056

Crase L, Gandhi VP (2009) Reforming institutions in water resource management: Policy and performance for sustainable development. Routledge

Farooq M, Shakoor A (2013) Severe energy crises and solar thermal energy as a viable option for Pakistan. J Renew Sustain Energy 5 (1):13104. https://doi.org/10.1063/1.4772637

Fornell C, Larcker DF (1981) Structural equation models with unobservable variables and measurement error: Algebra and statistics. J Mark Res 18(3):382–388

Gandhi VP, Johnson N (2019) Enhancing performance of participatory water institutions in the Eastern Indo-Gangetic plains: what can we learn from new institutional economics and governance theories? Water 12(1):70

Gandhi VP, Johnson N (2020) Enhancing performance of participatory water institutions in the eastern Indo-Gangetic plains: What can we learn from new institutional economics and governance theories? Water 12:70

Ghumman AR, Ahmad S, Hashmi HN, Khan R (2014) Comparative evaluation of implementing participatory irrigation management in Punjab, Pakistan. Irrig Drain 63:315–327

Güvercin Ö, Boz İ (2003) Üreticilerin sulu tarım konusundaki deneyimleri ve sulama birliklerine bakışı: Düziçi ilçesi örneği. KSÜ Fen Ve Mühendislik Dergisi 6(2):80–90

Hair J, Hollingsworth CL, Randolph AB, Chong AYL (2017) An updated and expanded assessment of PLS-SEM in information systems research. Ind Manag Data Syst 117(3):442–458

Haq S, Boz I, Shahbaz P, Yıldırım Ç (2020) Evaluating eco-efficiency and optimal levels of fertilizer use based on the social cost and social benefits in tea production. Environ Sci Pollut Res 27:33008–33019

Hone S, Crase L, Burton M, Cooper B, Gandhi VP, Ashfaq M, Lashari B, Ahmad B (2020) Farmer cooperation in participatory irrigation in South Asia: Insights from game theory. Water 12:1329

Hourneaux F Jr, da Silva Gabriel ML, Gallardo-Vázquez DA (2018) Triple bottom line and sustainable performance measurement in industrial companies. Revista De Gestão 25(4):413–429

Kazbekov J, Abdullaev I, Manthrithilake H, Qureshi A, Jumaboev K (2009) Evaluating planning and delivery performance of water user associations (WUAs) in Osh Province, Kyrgyzstan. Agric Water Manag 96(8):1259–1267

Manero A, Wheeler SA (2022) Perceptions of Tanzanian smallholder irrigators on impact pathways between water equity and socioeconomic inequalities. Int J Water Resour Dev 38(1):80–107

Mekonnen DK, Channa H, Ringler C (2015) The impact of water users' associations on the productivity of irrigated agriculture in Pakistani Punjab. Water Int 40(5–6):733–747

Mekonnen MM, Hoekstra AY (2016) Four billion people facing severe water scarcity. Sci Adv 2:e1500323

Mikalef P, Pateli A, van de Wetering R (2021) IT architecture flexibility and IT governance decentralization as drivers of IT-enabled dynamic capabilities and competitive performance: The moderating effect of the external environment. Eur J Inf Syst 30(5):512–540

Mochalova E (2014) Institutions as Key Drivers of Collective Action in WUAs of Uzbekistan. Gwangju, South Korea: Elizaveta Mochalova (Curator)

Muchara B, Ortmann G, Wale E, Mudhara M (2014) Collective action and participation in irrigation water management: A case study of Mooi River Irrigation Scheme in KwaZulu-Natal Province, South Africa. Water SA 40(4):699–708

Murtinho F, Tague C, De Bièvre B, Eakin H, Lopez-Carr D (2013) Water scarcity in the Andes: a comparison of local perceptions and observed climate, land use and socioeconomic changes. Hum Ecol 41(5):667–681

Nagrah A, Chaudhry AM, Giordano M (2016) Collective action in decentralized irrigation systems: Evidence from Pakistan. World Dev 84:282–298

Naseer, M.a.U.R., Ashfaq, M., Razzaq, A., and Ali, Q. (2020) Comparison of water use efficiency, profitability and consumer preferences of different rice varieties in Punjab, Pakistan. Paddy Water Environ, 18:273–282

Nosair AM, Shams MY, AbouElmagd LM, Hassanein AE, Fryar AE, Abu Salem HS (2022) Predictive model for progressive salinization in a coastal aquifer using artificial intelligence and hydrogeochemical techniques: A case study of the Nile Delta aquifer, Egypt. Environ Sci Pollut Res 29(6):9318–9340

Razzaq A, Qing P, Naseer, M.a.U.R., Abid, M., Anwar, M., and Javed, I. (2019) Can the informal groundwater markets improve water use efficiency and equity? Evidence from a semi-arid region of Pakistan. Sci Total Environ 666:849–857

Rehman Khan SA, Yu Z (2021) Assessing the eco-environmental performance: an PLS-SEM approach with practice-based view. Int J Log Res Appl 24(3):303–321

Riaz M, Ashfaq M (2019) Impact of participatory irrigation management on water availability and agricultural productivity. In conference: Australian Agricultural and Resource Economics Society (AARES), February 12–15, 2019, Melbourne, Australia (No. 2186–2019–1412)

Sarkar A, Azim JA, Al Asif A, Qian L, Peau AK (2021) Structural equation modeling for indicators of sustainable agriculture: Prospective of a developing country's agriculture. Land Use Policy 109:105638

Senanayake I, Dissanayake D, Mayadunna B, Weerasekera W (2016) An approach to delineate groundwater recharge potential sites in Ambalantota, Sri Lanka using GIS techniques. Geosci Front 7:115–124

Shahbaz P, Boz I, Haq SU (2017) Determinants of crop diversification in mixed cropping zone of Punjab Pakistan. Direct Res J Agric Food Sci 5(11):360–366

Shahbaz P, Haq SU, Boz I (2022) Linking climate change adaptation practices with farm technical efficiency and fertilizer use: A study of wheat–maize mix cropping zone of Punjab province, Pakistan. Environ Sci Pollut Res 29(12):16925–16938

Shahzadi A, Li S, Sahibzada UF, Malik M, Khalid R, Afshan G (2021) The dynamic relationship of knowledge management processes and project success: modeling the mediating role of knowledge worker satisfaction. Bus Process Manag J 27(6):1657–1676

Singh M, Liebrand J, Joshi D (2014) Cultivating "success" and "failure" in policy: participatory irrigation management in Nepal. Dev Pract 24:155–173

Srinivasan V, Kulkarni S (2014) Examining the emerging role of groundwater in water inequity in India. Water Int 39(2):172–186

Srivastav AL, Pham TD, Izah SC, Singh N, Singh PK (2021) Biochar adsorbents for arsenic removal from water environment: A review. Bull Environ Contam Toxicol 1–13.

Taheri B, Bititci U, Gannon MJ, Cordina R (2019) Investigating the influence of performance measurement on learning, entrepreneurial orientation and performance in turbulent markets. Int J Contemp Hosp Manag 31(3):1224–1246

Uysal ÖK, Atış E (2010) Assessing the performance of participatory irrigation management over time: A case study from Turkey. Agric Water Manag 97(7):1017–1025

Vafaei E, Ahangarkolaee SS, Lucas-Borja ME, Fami HS, Zema DA (2021) A framework to evaluate the factors influencing groundwater management in Water User Associations: The case study of Tafresh County (Iran). Agric Water Manag 255:107013

Wang C, Ma L, Zhang Y, Chen N, Wang W (2022) Spatiotemporal dynamics of wetlands and their driving factors based on PLS-SEM: A case study in Wuhan. Sci Total Environ 806:151310

Wang J, Huang J, Zhang L, Huang Q, Rozelle S (2010) Water governance and water use efficiency: The five principles of WUA management and performance in China 1. JAWRA J Am Water Resour Assoc 46(4):665–685

Yercan M, Atis E, Salali HECE (2009) Assessing irrigation performance in the Gediz River Basin of Turkey: water user associations versus cooperatives. Irrig Sci 27(4):263–270

Zhang L, Heerink N, Dries L, Shi X (2013) Water users associations and irrigation water productivity in northern China. Ecol Econ 95:128–136

Zulfiqar F, Shahzad S, Abid M, Ullah R (2017) Managing water commons and the extent of their climate resilience in Punjab, Pakistan. Conference Paper, Indiana University, Digital Library of Commons

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