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ARTICLE

Power Dynamics and Participatory Irrigation Water Management: Impacts on Farmer Satisfaction in Central Khyber Pakhtunkhwa Pakistan

***Abdul Zahir* [1*], *Asad Ullah* [1], *Osman Elwasila* [2], *Yonis Gulzar* [2*]**

[1] *Department of Rural Sociology, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa 25130, Pakistan*
[2] *Department of Management Information Systems, College of Business Administration, King Faisal University, Al-Ahsa 31982, Saudi Arabia*

ABSTRACT

This research aimed to assess collective and participatory irrigation water management in relation to farmers' satisfaction with water distribution in central Khyber Pakhtunkhwa, Pakistan. The study randomly selected 466 farmers using a multistage stratified random sampling technique, collecting data through interviews. Chi-square and Kendall's Tau-c tests and order logistic regression analysis were applied. Results revealed a significant and positive association between farmers' satisfaction and the village-level organizations managing irrigation (P = 0.000; T^c = 0.180), membership of these organization (P = 0.000; T^c = 0.174), planning of water management (P = 0.000; T^c = 0.169), collective participation in water management (P = 0.000; T^c = 0.176), rotational irrigation timeframe (P = 0.000; T^c = 0.092), and collectively planned water management activities (P = 0.004; T^c = 0.112). Similarly, by keeping farmers participate in irrigation management to a lesser extent as base category, the positive co-efficient indicates that the log odds for satisfaction with water distribution increases among farmer's participate in irrigation management to a greater extent (co-efficient = 1.681, OR = 5.37, P = 0.000) and farmers somewhat participate in irrigation management (co-efficient = 0.735, OR = 2.09, P = 0.003). The study concluded that community-driven ef-

*CORRESPONDING AUTHOR:
Abdul Zahir, Department of Rural Sociology, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa 25130, Pakistan; Email: zahir_uopesh@yahoo.com; Yonis Gulzar, Department of Management Information Systems, College of Business Administration, King Faisal University, Al-Ahsa 31982, Saudi Arabia; Email: ygulzar@kfu.edu.sa

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forts, once central to irrigation management, are now limited to seasonal maintenance of channels. Both irrigation authorities and influential farmers resist forming specific farmer organizations for water management. The study recommends establishing inclusive village-level irrigation committees to plan and implement strategies, ensuring representation for marginalized farmers to reduce dissatisfaction with water distribution.

Keywords: Collective Participation; Village Level Organization; Irrigation Timeframe; Stakeholders Representation; Khyber Pakhtunkhwa-Pakistan

1. Introduction

Sustainable agriculture and rational use of water resources is the major concern of sustainable development goal 2030 agenda. These concerns are directly or indirectly touched by some of sustainable development goals like improved clean water and sanitation, zero hunger, eliminate poverty, reduce inequality, organize climate action, influence responsible consumption and production, etc., to change the world for better [1]. Thus, satisfactory irrigation water distribution is based on a complex and multifaceted interaction of multiple variables. The concept of integrated water management is one of such attempts to cover the multiplicity of these factors in a single model for efficient water management for maximum socio-economic and environmental benefits [2, 3].

Integrated Water Resource Management (IWRM) approach was first introduced in 1933 by Tennessee Valley Authority (TVA) to integrate the navigation, flood control, power production, recreation, erosion control and public health functions of the river [4]. The concept of integrated water resource management was further highlighted by UN Secretary General in 1957 during his address which emphasized the coordination of water related functions [5]. However, until 1992 the conventional water management was recognized as insufficient to meet the growing population's need due to the ignorance of this system to quality issues, over exploitation, ecosystem degradation and social concern [4]. It was at this point that the Dublin Statement on Water and Sustainable Development was agreed, and four principles on water management were approved at the Earth Summit 1992 in Rio de Janeiro, and subsequently adopted by the Global Water Partnership (GWP). These principles emphasize that water is a finite and vulnerable resource, and its development and management should be based on a participatory approach. Women's involvement should be ensured in water management, and the social and economic value of water should be highlighted for its use. These integrated water resource management principles are also called ecological, institutional, gender and economic principles or simply called the Dublin principles [4–6]. The four principles of integrated water resource management give a holistic view of integrated water resource management paradigm that integrates the management of horizontal sectors (the sector that affect water use, e.g., water supply, sanitation, agricultural use, energy generation, industrial use and environmental protection, etc.) alongside vertical integration (co-ordination efforts between local, regional, national and international water user groups and institutions) [7]. The integrated water resource management is characterized by decentralized decision-making, a high level of awareness for local and regional problems, which balances top-down and bottom-up management. It ensures ecological, financial and economic sustainability through rational use of water in a scientific manner alongside pricing in full cost [6, 8].

Transformation of integrated water resource management paradigm into practice is a difficult task due to complexity of water cycle and interdependency of various water development sectors (e.g., food sector, fisheries, electricity, etc.) and multiple stakeholders in each sector (farmers, irrigation department, agriculture department and NGOs, etc.). In a nutshell, an appropriate framework of integrated water resource management will require thorough consideration for integrity of environmental, social and economic issues for a specific region or watershed area. The global water partnership, therefore, recommended and integrated water resource management planning cycle to transform integrated water resource management paradigm into practice [9, 10].

The integrated water resource management model is a famous and widely recognized and used model to understand the multiple contexts of water resource use and management. This model is based on decade-long practice and research to establish necessary interdisciplinary tools which come from natural sciences (hydrology & metrology, etc.), engineering (civil and structure engineering, etc.) and social sciences (sociology, economics & political science, etc.). The multiple variables of this model are arranged into three layered patterns of enabling environment, institutional roles and management instruments that shape the efficient water distribution and management to different users' groups [9, 11]. Irrigated agriculture has been considered as a panacea in many developing nations for dealing with endemic rural poverty by helping to enhance living standards and improve food security. However, institutional flaws in irrigation administration significantly diminish its performance and effectiveness [12]. During 1970s and 1980s, irrigation systems were developed based on the decisions of farmers known as "participatory irrigation management" (PIM) and "irrigation management transfer" (IMT). These approaches gave mixed-yield outcomes, particularly in India and Pakistan (Senanayake et al., 2015). Irrigation experts understood in the 1980s that the government alone could not manage and maintain irrigation infrastructure. They started to encourage farmers' roles in water resource management [12, 13]. By the early 1990s, international donors had followed suit, promoting policies that encouraged farmer participation in irrigation management (Vermillion, 1997) [14, 15].

Theoretically, this research study is based on multiple theories (Green perspective, Marxist theory, Homer-Dixon theory, Karl Wittfogel social theory of irrigation, and Tragedy of common resource theory) to explain factors affecting farmers' satisfaction with irrigation water allocation explained in integrated water resources management model.

The Green perspective emphasizes the interplay between socio-environmental and technological factors in shaping water use dynamics and related conflicts, centering around four key pillars: population, social organization, environment, and technology. Rapid population growth has intensified pressure on freshwater resources for agricultural, industrial, and domestic needs (Ardekanian, 2003; Tabara, 2007), while misapplied technologies further degrade water sources and the environment, widening the gap between supply and demand and fueling conflict among user groups (Green, 2002; Bijani & Hayati, 2011; Sadeghi et al., 2020). From a Marxist viewpoint, water conflicts stem from social inequality and power imbalances that favor dominant groups, leaving marginalized communities at a disadvantage and prone to resistance or conflict (Said, 2008; Tahir, 2009; Mohammadinezhad & Ahmadvand, 2020; Huffaker & Hamilton, 2007; Tulloch, 2009). Homer-Dixon (1994) identifies water scarcity as a result of supply, demand, and structural shortages, with governance systems needing to regulate population and adopt efficient technologies, though power misuse can create inequitable access. Wittfogel's theory highlights how irrigation bureaucracies evolve into power centers within agrarian societies, shifting influence from landowners to those controlling water distribution, thereby embedding water politics into broader socio-economic structures (Wittfogel, 1957; Ulmen, 1978).

This research study is limited to participatory irrigation management practices, which is a broad concept that empowers farmers to make collective decisions that influence their lives. It allows for collective action and conversation among users, agencies, and governments. Effective participation promotes fairness, efficient management, and effective water fee collection. Farmers' active participation in irrigation management helps to maintain the sustainability of irrigation systems by ensuring regular water deliveries and distribution of water, improved design and construction, reducing water conflicts, and enhancing irrigation system maintenance. When water user associations are given the authority to manage irrigation infrastructure improvements, they often explore several methods to prevent waste, control corruption, and allocate funds more efficiently. When rehabilitation is associated with the development of water user organizations, it not only strengthens the WUA's capabilities but also allows for ownership of the irrigation system [16]. Participatory initiatives can increase administrations' ability to listen to water users. They can develop and strengthen mechanisms for officials and farmers to collaborate on water allocation and problem resolution, thereby making them more efficient and accountable. Water rights are frequently allocated as shares under the warabandi system, necessitating careful coordination and negotiation to obtain the appropriate quantity of water at the proper time [17]. Moreover, an individual farmer cannot meet all their irrigation water related needs, especially, when such farmers are from the lower rung of social stratification hierarchy. Collective action in such situations helps the farmers to work together for common causes and achieve their individual and common goals [18–21]. The collective action is also a source to power balance with the powerful elites, individuals, groups and institutions. Participatory irrigation management empowers the farmers in various aspects of irrigation management ranging from planning, organizing, implementing, monitoring, evaluating and benefit distribution of irrigation system. In some instances, total irrigation management is transferred to farming community for participatory irrigation management and enabling communities in resolving their irrigation related problems by themselves to enhance their satisfaction in irrigation water distribution [22–26].

Therefore, the main aim and objective of this research is to study the extent to which the collective and participatory irrigation management can contribute to farmers' satisfaction with water distribution?

2. Materials and Methods

The main objective of this research paper is to examine collective and participatory irrigation water management in relation to farmer satisfaction with water distribution in three districts (Malakand, Charsadda, and Mardan) of central Khyber Pakhtunkhwa, Pakistan. These districts are irrigated through the Upper Swat Canal, which is divided into two branches: Abazai and Machi. These branches are further segmented into 27 minors and 508 outlets. The entire irrigation system is managed through three administrative sections: Dargai, Harichand, and Hatyan. A total of 27,830 farmers depend on and utilize irrigation water from these canals. A multistage stratified random sampling technique was used for sample selection. In the first and second stages, the Machi and Abazai canals, along with the three irrigation sections (Dargai, Harichand, and Hatyan), were selected. In the third stage, five minors out of nine were randomly selected from the Dargai section, five out of ten from the Harichand section, and four out of eight from the Hatyan section. At the fourth stage, 87 outlets out of 262 were selected using a systematic sampling procedure with a skip interval of 3. In the fifth stage, a total of 15,242 farmers using water from the selected 87 outlets were listed. These lists were obtained from the irrigation department and constituted the sampling frame for the present study. The sample size (n = 466) farmers were determined using Equation 1 proposed by Chaudhry (2009) [27], and Equation 2 used by Bowley (1926) was applied for proportional allocation and random selection [28], as shown in **Table 1**.

$$n = \frac{N\widehat{pq}Z^2}{\widehat{pq}Z^2 + Ne^2 - e^2} \quad (1)$$

$$\mathrm{n_h} = \frac{\mathrm{Nh}}{N} \times n \quad (2)$$

Table 1. Allocation of Required Sample to Selected Irrigation Section & Minors.

Selected Minors and Farmers from Dargai Irrigation Section					
S/No	**Selected Minors**	**Total Outlets on Each Minor**	**Selected Outlets from Each Minor**	**Total Number of Farmers on Each Minor**	**Sample Size from Each Minor**
1	PC Minor	31	10	1448	44
2	Abazai Branch	28	10	935	29
3	Jalala Minor	21	7	1191	36
4	Shengari Minor	13	4	896	27
5	Pirsado Minor	15	5	608	19
6	Sub Total	108	36	5078	155

Table 1. *Cont.*

Selected Minors and Farmers from Harichand Irrigation Section					
S/No	**Selected Minors**	**Total Number of Outlets on Each Minor**	**Selected Outlets from Each Minor**	**Total Number of Farmers on Each Minor**	**Sample Size from Each Minor**
1	Sharif Dheri Minor	10	3	234	8
2	Bariband Minor	39	13	2753	68
3	Amirabad Minor	24	8	1244	30
4	Behram Dheri Minor	16	5	489	12
5	Nusrat Zai Minor	14	5	512	20
6	Sub Total	103	34	5532	138
Selected Minors and Farmers from Hatyan Irrigation Section					
S/No	**Selected Minors**	**Total Number of Outlets on Each Minor**	**Selected Outlets from Each Minor**	**Total Number of Farmers on Each Minor**	**Sample Size from Each Minor**
1	Shergarh Minor	13	4	1443	54
2	Kalo Minor	21	7	1413	53
3	Sapokanda Minor	11	4	241	9
4	Hatyan Minor	6	2	1535	57
5	Sub Total	51	17	4632	173
Grand total for all selected irrigation sections		262	87	15242	466

2.1. Conceptual Framework

In this study, farmers' satisfaction with water distribution was the dependent variable, while collective and participatory irrigation water management, socio-economic status and age of the farmers were independent variables that constituted the conceptual model shown in **Table 2**.

2.2. Measurement of Variables

The collective and participatory irrigation water management variable was measured on the scales adopted from Shivakoti (1991) [29], Cheema et al. (1997) and Habtamu (2011) with slight modifications after approval from the departmental supervisory committee [30, 31]. The collective and participatory irrigation water management was grouped into three categories on the basis of average score i.e., farmers participate in irrigation management to greater extent (1.14 and below), farmers somewhat participate in irrigation management (1.141 to 1.71) & farmers participate in irrigation management to a lesser extent (above 1.71) and coded as 0, 1 and 2, respectively. Similarly, Udai Pareek and Kuppuswamy (2019) modified scales were used based on three variables, i.e., farmers' education, farmers' monthly income and land holding for measurement of farmers' socio-economic status [32]. Based on the scores level, the lowest possible score of these three mentioned domains measuring socio-economic status (SES) of the farmers became 2 and the highest score is 11. By using a quantitative approach, the score is divided into three groups, according to which farmers with a score of 2–5 on the socioeconomic status scale were ranked into low socioeconomic status farmers. Moreover, those in the range of 6–8 on the scale were considered as middle socio-economic status farmers, and those with scores 9–11 were considered as high socio-economic status farmers [31, 32].

Table 2. Conceptual Framework of the Study.

Independent Variables	**Dependent Variable**
Collective and participatory irrigation water management Farmers socio-economic status Age	Farmer's satisfaction with water distribution

2.3. Data Analysis

The Statistical Package for the Social Sciences (SPSS) version 20 was used to analyze the data at the bivariate and multivariate levels. The Bi-Variate analysis was used to find out the association between dependent and independent variables. The chi-square test was used to test the association between the two variables. The Chi Square test values were calculated using [33]

$$x^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(O_{ij} - e_{ij})^2}{e_{ij}} \quad (3)$$

The basic principles for the Chi-Square Test are given below

1. The subjects for each group are randomly and independently selected.
2. Each observation must qualify for one and only one category.
3. Sample size must fairly be large such that no expected frequency is less than 5, for r and c > 2 or < 10 if r = c = 2.

If the last principle was violated in the data, then the Fisher Exact Test was used instead of the simple Chi-Square Test. The Fisher Exact Test is expressed as follows

$$\text{Fisher Exact Test} = \frac{(\mathrm{a}+\mathrm{b})!(\mathrm{c}+\mathrm{d})!(\mathrm{a}+\mathrm{c})!(\mathrm{b}+\mathrm{d})!}{\mathrm{N}!\ \mathrm{a}!\mathrm{b}!\mathrm{c}!\mathrm{d}!} \quad (4)$$

The multivariate analysis was used to determine whether the variation in farmers' satisfaction with water distribution caused by the independent variables could be explained by the control variables or not. At the multivariate level, the variables that met the Cronbach's Alpha coefficient criteria for indexation were indexed and cross-tabulated with the dependent variable (farmer satisfaction with water distribution) while controlling for farmers' socio-economic status. The Chi-Square/ Fisher's exact test was used to analyze the relationship between variables, and the tau-c (T^c) test was used to determine the strength and direction of association among variables. Kendall's Tau-c is expressed as below (Nachmias, 1992).

$$T^c = \frac{2(\mathrm{nc}-\mathrm{nd})}{\mathrm{n}2\frac{(\mathrm{m}-1)}{\mathrm{m}}} \quad (5)$$

Order logistic regression model was used for analysis of quantitative data. Order logistic regression model is an ordinal regression model for ordinal endogenous variables. Following Bratti and Staffolani's (2011) procedure the outcome factors were in systematically ordered as highly satisfied with irrigation water distribution [34], moderately satisfied with irrigation water distribution and less satisfied with irrigation water distribution, and the explanatory variables were used in the ordered logistic model as below.

- Collective and participatory irrigation water management (0 = Farmers participate in irrigation management to a greater extent, 1 = Farmers somewhat participate in irrigation management, 2 = Farmers participate in irrigation management to a lesser extent)
- Socio-economic status (0 = Low Socio-economic status, 1.00 = Middle Socio-economic status, 2.00 = High Socio -economic status)
- Age (0 = Young adulthood (20–40 years), 1 = Middle age adulthood (41–60 years), 2 = Older adulthood (Above 60 years).
- Farmer's satisfaction with water distribution (0 = Low satisfied with irrigation water distribution, 1 = Moderately satisfied with irrigation water distribution, 2.00 = Highly satisfied with irrigation water distribution)

Since the ordered logistic regression used categorical variables, the following were taken as the base categories: farmers with less participation in irrigation management, farmers with high socio-economic status, and farmers in older age groups. These served as the reference groups for collective and participatory irrigation water management, socio-economic status, and age of respondents, respectively.

The mathematical form of the ordered logistic regression model used in this study to analyze the variables responsible for farmers' satisfaction with water distribution is written as:

$$\mathbf{y} = \beta 0 + \beta 1\, \boldsymbol{x}1 + \beta 2\, \boldsymbol{x}2 + \beta 3\, \boldsymbol{x}3 .... + \beta k\, \boldsymbol{x}k + \varepsilon i \quad (6)$$

where y represents dependent variable, $\beta 0$ indicates the intercept, $\beta 1$ signifies the regression coefficients for variables, and $\boldsymbol{x}1$– $\boldsymbol{x}$k denote the fixed values of the independent variables and εi is the error term [35]. In this research study, the specification of the ordered logistic regression model is given below;

$$\text{Y (farmer's satisfaction with water distribution)} = \beta 0 + \beta 1\text{(collective and participatory irrigation water management)} + \beta 2\text{(Socio-economic status)} + \beta 3\text{(Age)} + \varepsilon i$$

For the ordinal logistic regression analysis, the following assumptions were tested in the following order

1. The regress and variables are in sequence.
2. Exogenous variables are either continuous, categorical or ordinal
3. No multi-collinearity issue
4. Proportional odds

3. Results and Discussion

3.1. Association between Collective and Participatory Irrigation Water Management and Farmers' Satisfaction with Water Distribution

The formal and informal organizations are important in defining planning, implementing and regulating irrigation water distribution. However, combining both of these formal and informal organizations can enhance the water management efficiency to a greater level. In real life involvement of informal organizations and community members in management of public resources is made possible through collective and participatory approaches. Under collective and participatory irrigation management, the community members and their informal organizations are delegated with greater power and more responsibilities to plan, implement and control irrigation water distribution in collaboration with irrigation department and other line agencies. Thus, under participatory approach, people share power and responsibilities with irrigation department to manage water resources to the satisfaction of farming community. Association between collective and participatory water management and farmer's satisfaction with water distribution is tested by limiting variable of collective and participatory irrigation to few attributes given in **Table 3** and explained below.

Table 3 results show that farmers' satisfaction with water distribution had a highly significant (P = 0.000) and positive (T^c = 0.180) association with having village level organizations to look after irrigation management. Similarly, a positive (T^c = 0.174) and a highly significant (P = 0.000) association was found between farmers' satisfaction with water distribution and village organizations having membership from all socio-economic status groups. Social organizations and resource mobilization are instrumental in establishment of village level organizations under collective and participatory irrigation water management endeavor. For this purpose, village level organizations are established through a democratic electoral process. These organizations are characterized with representation from all socio-economic status, cast, religion and ethnicity groups to ensure incorporation of all stakeholders in the planning process and their subsequent resolution. Establishment of village level organization under participatory approach with greater representation of all stakeholders is more likely to solve the water distribution problem according to the aspiration of all farmers group and lead to their greater satisfaction from water distribution as evident from above significant and positive results. Irrigation water distribution and management is the administrative authority of irrigation department. However, it is very difficult for overloaded irrigation staff with least facilitation to shoulder the heavy work load. Moreover, the elements of social inequality, power imbalances, corruption damage the spirit of fair irrigation water distribution. To overcome social inequality and ensure fair and efficient water distribution the collective and participatory irrigation water management approaches are introduced which involve functional participation of all stakeholders in irrigation water management at village level (Yohannes et al., 2006) [36]. Consequently, the workload of irrigation department in planning, implementing and regulating irrigation water distribution and maintenance of irrigation infrastructure is shoulder by the community members (Bijani and Hayati, 2018) [37, 38]. Moreover, incorporation of the sway of all stakeholders creates the sense of ownership among farming community. Such farmers are free to describe their problems at community level meeting, suggest its remedy, and ensure transparency in the system and promote fair water distribution to the satisfaction of the farmers (Ghasemi, 2006) [3, 37, 39, 40].

Table 3. Association Between Collective and Participatory Water Management and Farmers' Satisfaction with Water Distribution.

Independent Variable (Collective and Participatory Water Management)	Dependent Variable	Statistics-χ2, (P = Value) & T^c
You have a village-level organization to look after irrigation management.	Farmer's satisfaction with water distribution	χ2 = 21.082 (0.000) T^c = 0.180
The village organizations have membership from all SES groups.	Farmer's satisfaction with water distribution	χ2 = 23.140 (0.000) T^c = 0.174
All farmers collectively plan their water management activities.	Farmer's satisfaction with water distribution	χ2 = 10.916 (0.004) T^c = 0.112
The water management practices are so planned at village level that no one is left.	Farmer's satisfaction with water distribution	χ2 = 21.344 (0.000) T^c = 0.169
The affairs of village-level water management activities are collectively participated in.	Farmer's satisfaction with water distribution	χ2 = 23.312 (0.000) T^c = 0.176
Warabandi is determining by mutual conscience of farmers and irrigation department?	Farmer's satisfaction with water distribution	χ2 = 20.408 (0.000) T^c = 0.092
Farmers contributing labor for maintenance of irrigation channels	Farmer's satisfaction with water distribution	χ2 = 1.460 (0.482) T^c = 0.053

Furthermore, the result of farmers' collectively planned water management activities showed a significant and positive (P = 0.004, T^c = 0.112) association with farmers' satisfaction with water distribution. In addition, planning water management practices at village level so that no one is left behind had highly significant and positive (P = 0.000; T^c = 0.169) association with farmers' satisfaction with water distribution. Collectivity is the beauty of all participatory approaches. The village organizations established after social organization process are mandated to sit together, identify major irrigation water distribution-related problems, suggest interventions for overcoming the problems and implement these interventions in a collective and participatory manner. In this whole planning process, specific attention is given to ensure that stakeholders from all socio-economic statuses, especially the marginalized segments, are involved in irrigation water management planning and implementation, so that no one is left behind. The collective and participatory planning has the beauty of diversity of viewpoints in problem identification and solution or suggestion from all stakeholders' groups. Moreover, such collective efforts are leading to a greater sense of ownership among all stakeholders that lead to a greater satisfaction with water distribution among farmers. The collective participatory approach enhances the confidence level of marginalized farmers by encouraging them to share their problems and possible solutions during the participatory planning process. Moreover, the discussion over problems and consensus development for possible solution reduces the chances of water-based conflicts among the farmers. Additionally, participatory planning and its implementation under the supervision of government authorities improve the trust level between the irrigation department and community members [40, 41]. Moreover, the stakeholders involved in participatory irrigation planning are more enthusiastic for shouldering the responsibility in implementation of these plans resulting in greater sustainability, reduced consumers cost, improved efficiency, fairness and efficient service delivery (Wodi, 2006) [38, 42–44].

Moreover, farmers' satisfaction with water distribution was found highly significant (P = 0.000) and positive (T^c = 0.176) in association with the collective participation for dealing with the affairs of village-level water management activities. Similarly, determining Warabandi (rotational water distribution) through mutual consensus of farmers and irrigation department exhibited a highly significant and positive association with farmers' satisfaction with water distribution (P = 0.000; T^c = 0.092). The community-based participatory approaches are tested during their implementation. Once the community is organized and plans are developed through mutual consensus of all stakeholders, these plans are approved by the competent authority, mostly an officer of the irrigation department of high rank. These plans are reviewed, improved and presented to community for any feedback. The finalized plans are approved and implemented. The government's share of financial contribution for plan implementation is released on annual, seasonal or monthly basis, while the financial share from community is contributed through cash collection from them or in kind (free and subsidized labor supply), according to mutually agreed and signed agreement. Thus, a village irrigation plan becomes a legal document under which the irrigation activities are planned and agreed upon by the irrigation department and local community and is implemented by all stakeholders collectively. The beauty of these plans lies in the collective planning and implementing processes where technical and social aspects of irrigation water management are thoroughly catered for through inputs from irrigation department experts and community representatives. Taleghani (2016) reported that collective and participatory irrigation water management processes are ideal but not smooth [45]. It involves persuading big farmers to share their power, authority and resources with poor farmers. Moreover, consensus development on irrigation water distribution, resource allocation, financial collection and responsibility distribution is quite difficult and time-consuming. In addition, the elements of elite capture in subgroups at the community level are an additional drawback of collective and participatory approaches. Lastly and more importantly willingness of irrigation department authority to delegate and share their administrative power with community members is the most important assumption for successful collective and participatory irrigation water management (Ndlovu et al., 2006) [8, 36, 40, 41].

On the other hand, farmers' satisfaction with water distribution and farmers contributing labour for maintenance of irrigation channels was found to be non-significant in association with each other (P = 0.442; T^c = 0.053). The collective and participatory irrigation water management is founded on zeal for collective efforts. Under this approach, the physical and financial responsibilities are shared by community members with irrigation department. Thus, the stakeholders from the community are bound to assist the irrigation department in desilting and maintaining the irrigation infrastructure by providing it free of cost or at a subsidized level. However, such cooperation was not fully extended by the farmers due to the infancy of this approach in the study area, which is not reflected in the non-significant association results. Theis et al. (2018) reported that community members are bound to facilitate the irrigation department by providing labor force to them during cleaning and maintenance of irrigation channels and canals. Such a labor supply is necessary for smooth and persistent water flow to agricultural fields. However, due to low wages fixed by the irrigation department and delayed payment, it reduces labor supply from the community side to the irrigation department (Wodi, 2006) [38, 46].

3.2. Association between Collective and Participatory Water Management and Farmer's Satisfaction with Water Distribution (Controlling Farmers Socio-Economic Status)

Table 4 results highlighted that the association of collective and participatory water management and farmers' satisfaction with water distribution in the context of low socioeconomic status farmers was positive (T^c = 0.141) and highly significant (P = 0.000). The association of above variables in the context of farmers with middle socioeconomic status was positive (T^c = 0.213) and highly significant (P = 0.000) and association of the said variables was positive but non-significant (P = 0.279 & T^c = 0.075) for high socio-economic status farmers. The significance value and T^c for the whole table showed highly significant and positive association (P = 0.000 & T^c = 0.164) between collective and participatory water management and farmer's satisfaction with water distribution of varying socioeconomic status groups. The association of collective and participatory water management with farmer's satisfaction with water distribution is explained by socio economic status of the farmers. As farmers from low and middle socio-economic status are significantly and positively affected by collective and participatory water management with respect to their satisfaction with water distribution than high socio-economic status farmers, as indicated by positive T^c. Passive participation of the majority of farmers in irrigation water management is identified as an obvious factor in the unequal and unfair distribution of irrigation water. Collective and participatory approaches in irrigation water management are introduced to ensure participation of farmers from all socio-economic, ethnic, and religious groups in planning and management of irrigation water. Involvement of farmers in planning and implementing irrigation water distribution regulates the water distribution and upkeeps the irrigation infrastructure to the required standard, and ensures smooth flow of irrigation water to all farmers. Moreover, this approach provides a remedial measure in case of problems faced by farmers through a participatory evaluation and feedback mechanism. In reality, the participatory irrigation water management, especially in developing countries like Pakistan, is not working smoothly. The administrative interruption, opposition from big farmers and the elements of elite capture are major hindrances in smooth working of collective and participatory approaches. Consequently, the high socio-economic status farmers are in different to collective participatory approaches, while the influence of these participatory irrigation water management approaches positively influence the satisfaction of low and middle socio-economic status groups. Various international organizations recommend collective and participatory irrigation water management for realistic problem identification and effective solution through involvement of farming communities. For this purpose, the farmers are socially organized into village level organizations and involved in participatory planning and implementation in water management plan through active participation of all stakeholders [22, 47–49]. The working of village organizations is guided by the principle of voluntarism and self-help to solve collective problems within the available resources under the technical and administrative guidance of government authorities [31, 50]. However, the farmers from high socio-economic status, in most cases, steer the working of village organizations in favor of personal needs through the element of elite capture (Gring, 2024) [48, 51, 52]. Farmer's participation in irrigation activities is likely to enhance their satisfaction in irrigation water distribution. However, due to non-existence of irrigation water related NGOs, and overloaded irrigation department establishment, participation of all stakeholders in water management under collective participatory approaches is not fair. Farmers from high socio-economic status groups manage to hijack these participatory organizations for their personal interest or forcefully stop them from working [22, 26, 31, 50, 52].

Table 4. Association Between Collective and Participatory Water Management and Farmer's Satisfaction with Water Distribution (Controlling Farmers Socio-Economic Status).

Socio-Economic Status of the Respondents	Independent Variable	Dependent Variable	Statistics χ2, Chi-Square (P = Value) & T^c	Statistics, χ2, Chi-Square (P = Value) & T^c for Overall Table
Low socio-economic status	Collective and participatory irrigation management	Farmer's satisfaction with water distribution	χ2 = 25.506 (0.000) T^c = 0.141	χ2 = 53.727 (0.000) T^c = 0.164
Middle socio-economic status	Collective and participatory irrigation management	Farmer's satisfaction with water distribution	χ2 = 37.049 (0.000) T^c = 0.213	
High socio-economic status	Collective and participatory irrigation management	Farmer's satisfaction with water distribution	χ2 = 5.077 (0.279) T^c = 0.075	

3.3. Estimated Model for Farmers' Satisfaction with Irrigation Water Distribution

Farmers satisfaction with irrigation water distribution was measured through ordered logistic regression model, as the dependent variable (farmers satisfaction with water distribution) is measured at ordinal level which include information on rank ordering (low satisfied with irrigation water distribution, moderately satisfied with irrigation water distribution and highly satisfied with irrigation water distribution) within data. The four prerequisite assumptions were tested before conducting ordinal logistic regression which include the following principles,

3.3.1. Assumption that the Dependent Variable is Ordered

As the dependent variable is measured at ordinal level and include information on rank ordering, therefore, the first assumption of ordered regression model, i.e., the dependent variable is order, is satisfied by the dataset.

3.3.2. Assumption that the Independent Variables are Categorical or Ordinal

The second assumption of ordered regression model is satisfied as all the independent variables are categorical or ordinal.

3.3.3. Multicollinearity Diagnostic Test

One of the fundamental assumptions is that there is no multi-collinearity issue among the set of independent variables in ordered logistic regression. For testing this assumption, variance inflation/ increase factor (VIF) test is used, in addition, the values of tolerance for each of independent variables are calculated (**Table 5**). All the independent variables exhibited the VIF values of less than 10 (**Table 5**). Furthermore, the tolerance values for each independent variable were higher than 0.10 (**Table 5**). Therefore, the assumption of multi collinearity was satisfied as the condition of no multiple relations between the independent variables introduced in the model was established from the VIF and tolerance values (Stephen and Karen, 2011) [53].

3.3.4. Assumption of Proportional Odds and Parallel Test

One of the major assumptions of the ordered logistic regression is that the effect of each independent variable is consistent/proportional through different thresholds. This assumption is termed the assumption of parallel odds or parallel lines. To test this assumption, the parallel line test was applied. This test (**Table 6**) compared the ordinal model (labelled as null hypothesis; **Table 6**) having a single set of coefficients for all thresholds with another model (labelled as general; **Table 6**) having a separate set of coefficients for each threshold. The ordinal model (proportional odds) gives significantly better fit to data than general model ($P = 0.147$; **Table 6**); therefore, the assumption of proportional odds is satisfied and the data is suitable for order logistic regression.

Table 5. Multicollinearity Diagnostic Test.

	Collinearity Statistics	
	Tolerance	**VIF**
Collective participatory irrigation water management	0.520	1.925
Socio-economic status of the respondents	0.933	1.071
Age	0.930	1.075

Table 6. Test of Parallel Lines.

Model	−2 Log Likelihood	Chi-Square	Df	Sig.
Null Hypothesis	460.888	19.498	14	0.147
General	411.308			

3.4. Order Logistic Regression Model

3.4.1. Variable Selection in the Ordered Logistic Regression Model

Three predictor variables, i.e., collective and participatory irrigation water management, socio-economic status, and age, exhibited significant relationship ($P < 0.05$) in ordinal logistic regression model to explain the variations in outcome variable (farmer's satisfaction with water distribution). In this research study, the specification of ordered logistic regression model is given as below:

$$\text{Y (farmer's satisfaction with water distribution)} = \beta 0 + \beta 1\text{(collective and participatory irrigation water management)} + \beta 2\text{(socio-economic status)} + \beta 3\text{(age categories)} + \varepsilon i$$

3.4.2. Model Fitting Information

It is essential to find out whether the ordered logistic regression model improves our ability to guess the outcome or not, before analyzing the effect of independent variables in the model. This is made possible by comparing the intercept-only model (model with no explanatory variable) with the final model (model with all explanatory variables). Results in **Table 7** show the comparison of the final model and the intercept-only model (using negative log-log link likelihood values). The Chi-Square value (χ^2 = 64.252) and highly significant result (P = 0.000)) suggest that the final model significantly improved the ability to guess the outcome as compared to the intercept-only model. Therefore, the ordered regression model enclosing all the explanatory variables like collective and participatory irrigation water management, socio-economic status, and age categories gives better prediction than if results are estimated by marginal probabilities for the outcome categories (low, moderate and highly satisfied with irrigation water distribution).

3.4.3. Goodness of Fit

The goodness of fit statistics is intended to test whether the collected data is consistent with the fitted model or not. The goodness of fit table (**Table 8**) contains Chi-Square statistics for the model and Chi-Square statistics based on deviance. The null hypothesis for goodness of fit assumes that the fit is good. If this null hypothesis is proved ($P > 0.05$), then it is concluded that the data and the model have similar predictions and the model is a good fit. If the null hypothesis is rejected ($P \leq 0.05$) then the model doesn't fit well with the data. The results in **Table 8** suggest that the model is a good fit (P = 0.119). Furthermore, the group of predictor variables exhibited significant relationship with dependent variable (Nagelkerke R^2 = 0.148; **Table 8**). The same statistic also helps to establish that 14.8 percent variation in farmer's satisfaction with water distribution is explained by grouping variables (**Table 8**). The low value of R^2 (0.148) is consistent with other cross-sectional study data where the value of Pseudo R-Square is typically low to moderately low, especially when the variables are of qualitative nature (Gujrati and Porter, 2009).

3.4.4. Factor Influencing Farmer's Satisfaction with Water Distribution Using Ordered Logistic Model

In the ordered logistic regression, which used categorical variables, the base categories were set as farmers with low participation in irrigation management, farmers belonging to higher socio-economic status, and farmers from older age groups. These categories were used as reference groups for comparing collective irrigation management, socio-economic status, and age of the respondents.

Parameter estimates, which elaborate on the specific relationship between the independent and dependent variables, are given in **Table 9**. The results of Wald test (**Table 9**) and its corresponding p-values validate that the grouping variables were significant in prediction of farmer's satisfaction with water distribution. The variables like collective and participatory irrigation water management, and age, are significant at five percent, while the socio-economic status of farmers is significant at one percent.

Moreover, by keeping farmers participate in irrigation management to a lesser extent as base category, the positive co-efficient estimate (**Table 9**) value indicate that the log odds for farmers satisfaction with water distribution increases among farmers participate in irrigation management to a greater extent (co-efficient estimate = 1.681, OR = 5.37, P = 0.000) and farmers somewhat participate in irrigation management (co-efficient estimate = 0.735, OR = 2.09, P = 0.003). Thus, while comparing to the farmers who least participate in irrigation management, farmers who participate in irrigation management to some extent or more are more likely to be satisfied with irrigation water distribution. Similarly, the negative value of co-efficient estimate in **Table 9** shows that farmers from low and middle socioeconomic status group are less likely to be satisfied with irrigation water distribution while keeping high socio-economic status of the farmers as a base category (low SES coefficient estimate = −1.775, OR = 0.17, P = 0.000), (middle SES co-efficient estimate = −1.579, OR = 0.21, P = 0.000). Thus, farmers from high SES are more likely to be satisfied with irrigation water distribution than those from low and middle SES groups. The reasons for the high satisfaction of farmers from high SES groups can be categorized into two broader groups. Initially, there are socio-economic characteristics owned by the farmers from high SES group that favor their better satisfaction with water distribution. For instance, farm size, availability of finances, literacy level, and access to communication channels for innovative technologies had substantial effects on farmer's attitudes toward awareness of innovative technologies, understanding these technologies, and practicing efficient and water conserving irrigation technologies at their farms. This means that high SES provides sound basis for positively accessing and adopting innovative technologies, while remaining within the due limit of irrigation water rights admissible to high SES farmer [54, 55]. On the other hand, the power and authority associated with high SES is a source of influence over irrigation administration, applied for, by high SES farmers, to get an unauthorized share of water, larger than their due right, at the cost of depriving the small and middle farmers [56]. In addition, the powers of high SES farmers don't allow the community-based and participatory irrigation water management committees to be established. If established, the powerful farmers don't let such organizations work in a fair manner or hijack them to accomplish their personal interests [50]. Consequently, the low SES farmers are more liable to water shortage, especially in Pakistan [52, 57].

Table 7. Model Fitting Information.

Model	−2 Log Likelihood	Chi-Square	Df	Sig.
Intercept Only	592.225			0.000
Final	527.973	64.252	5	

Table 8. Goodness-of-Fit.

	Goodness-of-Fit			Pseudo R-Square		
	Chi-Square	Df	Sig.	Cox and Snell	Negelkerke	McFadden
Pearson	381.369	350	0.119	0.128	0.148	0.068
Deviance	365.020	350	0.279			

Table 9. Factors Influencing Farmers' Satisfaction with Water Distribution Using Ordered Logistic Model.

	Estimate	Odds Ratio	Std. Error	Wald	Df	Sig.
Low satisfied with irrigation water distribution	−1.488	0.23	0.535	7.727	1	0.005
Moderately satisfied with irrigation water distribution	0.248	1.28	0.530	0.219	1	0.640
Farmers participate in irrigation management to a greater extent	1.681	5.37	0.326	26.568	1	0.000
Farmers somewhat participate in irrigation management	0.735	2.09	0.251	8.586	1	0.003
Farmers participate in irrigation management to a lesser extent	0^a				0	
Low socio-economic status	−1.775	0.17	0.444	15.971	1	0.000
Middle socio-economic status	−1.579	0.21	0.428	13.580	1	0.000
High socio-economic status	0^a		.	.	0	.
Young adulthood (20–40 years)	−0.213	0.81	0.301	0.502	1	0.479
Middle-aged adulthood (41–60 years)	−0.565	0.57	0.257	4.816	1	0.028
Older adulthood (above 60 years)	0^a				0	

Furthermore, by keeping farmers of older age adulthood as base category, the negative co-efficient estimate value indicates that log odds for farmer satisfaction from water distribution decreased among farmers of middle age adulthood (co-efficient estimate = −0.565, OR = 0.57, P = 0.028), and farmers of young age adulthood (co-efficient estimate = −0.213, OR = 0.81, P = 0.479). It is interpreted from the odds ration that farmers from young and middle age group are less likely to satisfy with irrigation water distribution than old age adulthood farmers. Age based experience is an important factor in making rational and informed decision related to irrigation water management. Experienced farmer is well aware of their water use right and are in better position to plan and implement their irrigation schedule in an efficient manner. Age gradations at family level receive distinct cultural and moral responses. Older adults receive the highest esteem and are responsible for overall strategic decision like participation in collective activities and settlement of major disputes. The middle-aged adults are generally responsible for planning and supervising field's level activities, while the young adulthoods are directly responsible for irrigating fields, cleaning water passages and ensuring smooth flow of irrigation water through water channel (Dlangalala, 2009) [58]. The household is headed by old adulthood age group farmers, who share some of their strategic responsibilities with middle adulthood age group farmers to streamline their transition as household head [59]. The strategic planning of irrigation water distribution involves safeguarding one's own rights without interfering with irrigation water related rights of other farmers. Thus, farming experience improves such skills of the farmers that improve satisfactory co-existence with other farmers and create a win-win situation for all stakeholders [37, 60, 61].

4. Conclusions and Recommendations

It is concluded that collective and participatory irrigation water management is focused on active involvement of community members in planning, implementing, controlling and overall management of irrigation water distribution. The participatory approaches are so designed to ensure active participation of all community-level stakeholders and government agencies in irrigation water management processes. This approach is beneficial, successful, and motivating community members from all segments of society to come up with their problems and solve these problems by themselves. In this way, some of the responsibilities of the irrigation department are shouldered by community members, as well. However, unwillingness of irrigation department and powerful segment of community to share their power and authority with the marginalize groups is potential threats to collective participatory irrigation water management. Yet active involvement of community members and collective participatory irrigation water management through cost and benefit sharing ensure enhanced farmer's satisfaction with water distribution. Therefore, farmers from high socio-economic status are more likely to be satisfied with irrigation water distribution than those from low and middle socio-economic status groups. Similarly, those farmers who participate in irrigation management to somewhat or a greater extent are more likely to be satisfied with irrigation water distribution while farmers from young and middle age group are less likely to satisfy with irrigation water distribution than old age adulthood farmers. Therefore, this study recommends to establish irrigation water committees at village level with representation from all stakeholder groups to plan and implement the irrigation plans in a participatory manner while taking special care of marginalized farmers can reduce farmer's dissatisfaction with water distribution.

Author Contributions

Conceptualization, A.Z., A.U., O.E., and Y.G.; methodology, A.Z., and A.U.; software, A.U., O.E., and Y.G.; validation, A.Z., A.U., O.E., and Y.G.; formal analysis, A.Z., and A.U.; investigation, A.Z., A.U., O.E., and Y.G.; resources, O.E., and Y.G.; data curation, A.Z.; writing—original draft preparation, A.Z., A.U.; writing—review and editing, A.Z., A.U., O.E., and Y.G.; visualization, A.Z., A.U., O.E., and Y.G.; supervision, A.U.; project administration, O.E., and Y.G.; funding acquisition, O.E., and Y.G. All authors have read

and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Ethical review and approval were waived for this study because it involved only voluntary interviews with adult farmers, carried out with informed consent, and did not include sensitive personal or medical data. The research was conducted in accordance with the ethical principles outlined by the American Psychological Association (APA).

Informed Consent Statement

Not applicable, as the study does not include any identifiable personal data or images of individual participants.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Due to privacy and ethical restrictions, the raw interview transcripts and survey responses cannot be publicly shared.

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Conflicts of Interest

The authors declare no conflict of interest.

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